

CARNEGIE INSTITUTION
OF WASHINGTON

Year Book

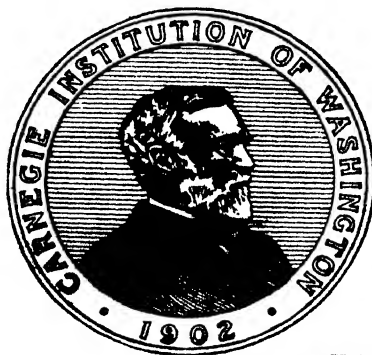
No. 37

CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 37

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Committee on Biological Sciences

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JAMES F. BELL	STEWART PATON

Committee on Historical Research

HENRY R. SHEPLEY, *Chairman*

ROBERT WOODS BLISS	RICHARD P. STRONG
CHARLES A. LINDBERGH	CHARLES P. TAFT

* On January 1, 1939, Dr. Merriam becomes President Emeritus, and Dr. Vannevar Bush succeeds him as President of the Institution.

FORMER PRESIDENTS AND TRUSTEES

PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

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ALEXANDER AGASSIZ	1904-05	SETH LOW	1902-16
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WILLIAM E. DODGE	1902-03	WM. BARCLAY PARSONS	1907-32
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	HENRY S. PRITCHETT	1906-36
WILLIAM N. FREW	1902-15	ELIHU ROOT	1902-37
LYMAN J. GAGE	1902-12	JULIUS ROSENWALD	1929-31
CASS GILBERT	1924-34	MARTIN A. RYERSON	1908-28
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DANIEL C. GILMAN	1902-08	JOHN C. SPOONER	1902-07
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HENRY HITCHCOCK	1902-02	ANDREW D. WHITE	1902-16
WILLIAM WIRT HOWE	1903-09	EDWARD D. WHITE	1902-03
CHARLES L. HUTCHINSON	1902-04	HENRY WHITE	1913-27
SAMUEL P. LANGLEY	1904-06	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR THE YEAR 1938

PHYSICAL SCIENCES

Advisory Committee on Physical Sciences: F. E. WRIGHT, *Chairman*

L. H. ADAMS
W. S. ADAMS
J. A. FLEMING

H. A. SPOEHR
J. STEBBINS
E. B. WILSON

Geophysical Laboratory

Organized in 1906, opened in 1907; Arthur L. Day, Director 1907-1936.

L. H. ADAMS, *Director*
JOHN S. BURLEW
ALLEN CROCKER
JOSEPH L. ENGLAND
MICHAEL FLEISCHER
R. E. GIBSON
R. W. GORANSON
J. W. GREIG
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EARL INGERSON
F. C. KRACEK
C. J. KSANDA
O. H. LOEFFLER

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G. W. MOREY
E. F. OSBORN
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H. S. ROBERTS
J. F. SCHAIER
E. S. SHEPHERD
GEORGE TUNELL
W. D. URRY
F. E. WRIGHT
E. G. ZIES

Mount Wilson Observatory

Organized in 1904; George E. Hale, Director 1904-1923, Hon. Director 1923-1936.

WALTER S. ADAMS, *Director*
F. H. SEARES, *Assistant Director*
ALFRED H. JOY, *Secretary*
A. S. KING, *Supt. Physical Laboratory*
J. A. ANDERSON
WALTER BAADÉ
HAROLD D. BABCOCK
WILLIAM H. CHRISTIE
THEODORE DUNHAM, JR.
JOSEPH HICKOX
EDISON HOGE
EDWIN P. HUBBLE

MILTON L. HUMASON
PAUL W. MERRILL
RUDOLPH MINKOWSKI
SETH B. NICHOLSON
EDISON PETTIT
R. S. RICHARDSON
R. F. SANFORD
GUSTAF STRÖMBERG
A. VAN MAANEN
OLIN C. WILSON
RALPH E. WILSON

Department of Terrestrial Magnetism

Organized in 1904; L. A. Bauer, Director 1904-1929.

J. A. FLEMING, *Director*
O. H. GISH, *Assistant Director*
L. V. BERKNER
F. T. DAVIES
S. E. FORBUSH
JOHN W. GREEN
L. R. HAFSTAD
N. P. HEYDENBURG
E. A. JOHNSON
H. F. JOHNSTON
P. G. LEDIG
A. G. MCNISH
R. C. MEYER

WILFRED C. PARKINSON
RICHARD B. ROBERTS, *Fellow*
W. J. ROONEY
W. E. SCOTT
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K. L. SHERMAN
H. E. STANTON
OSCAR W. TORRESON
M. A. TUVE
E. H. VESTINE
G. R. WAIT
W. F. WALLIS
H. W. WELLS

DIVISION OF PLANT BIOLOGY: H. A. SPOEHR, *Chairman*

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

JENS C. CLAUSEN
FREDERIC E. CLEMENTS
WALDO S. GLOCK
WM. M. HIESEY
DAVID D. KECK
FRANCES L. LONG

T. D. MALLERY
EMMETT MARTIN
H. W. MILNER
FORREST SHREVE
JAMES H. C. SMITH
H. H. STRAIN

DIVISION OF ANIMAL BIOLOGY: GEORGE L. STREETER, *Chairman*

An administrative grouping made effective in 1935, including activities of the following Departments:

Department of Embryology

Organized in 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, *Director*
CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS
CHARLES W. METZ

Department of Genetics

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934.

A. F. BLAKESLEE, *Director*
M. DEMEREC, *Assistant Director*
H. H. LAUGHLIN, *Assistant Director*
A. G. AVERY
R. W. BATES
A. DOROTHY BERGNER
B. P. KAUFMANN

E. C. MACDOWELL
JAMES S. POTTER
OSCAR RIDDLE
SOPHIA SATINA
J. P. SCHOOLEY
MORRIS STEGGERDA
H. E. WARWICK

Nutrition Laboratory

Organized in 1907, opened in 1908; F. G. Benedict, Director 1907-1937.

T. M. CARPENTER, *Acting Director*
V. COROPATCHINSKY

ROBERT C. LEE

Tortugas Laboratory

Established in 1904. Alfred G. Mayor, Director 1904-1922; W. H. Longley, Executive Officer 1924-1937. Open for marine biological studies during summer months.

D. H. TENNENT, *Executive Officer*
P. S. CONGER, *Assistant Executive Officer*

DIVISION OF HISTORICAL RESEARCH: A. V. KIDDER, *Chairman*

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

Section of Aboriginal American History

SYLVANUS G. MORLEY
EARL H. MORRIS
H. E. D. POLLOCK
O. G. RICKETSON, JR.
KARL RUPPERT
ANNA O. SHEPARD
A. LEDYARD SMITH
GUSTAV STRÓMSVIK
J. ERIC THOMPSON

Section of Post-Columbian American History

ROBERT S. CHAMBERLAIN
RALPH L. ROYS
FRANCE V. SCHOLES
LEO F. STOCK

Section of the History of Science

GEORGE SARTON
ALEXANDER POGO
MARY WELBORN

RESEARCH ASSOCIATES

<p>ERNST ANTEVS, Climatology MARION E. BLAKE, Archæology BENJAMIN BOSS, Astronomy C. B. BRIDGES, Biology BARBARA S. BURKS, Genetics ALFONSO CASO, Archæology VERNE E. CHATELAIN, History PAUL S. CONGER, Biology H. deTERRA, Archæology and Palæontology A. E. DOUGLASS, Climatology</p>	<p>NEWTON B. DRURY, Study of Primitive Areas ROBERT EMERSON, Biology CHARLTON M. LEWIS, Physics F. A. PERRET, Geophysics HARRY RAYMOND, Astronomy ARTHUR J. ROY, Astronomy JACK SCHULTZ, Biology HARRY O. WOOD, Seismology S. YAMANOUCHI, Biology</p>
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Research Associates Engaged in Post-retirement Studies

<p>F. G. BENEDICT, Nutrition EDMUND C. BURNETT, History</p>	<p>CHARLES B. DAVENPORT, Biology ARTHUR L. DAY, Geophysics</p>
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Research Associates Connected with Other Institutions

SOPHIE D. ABERLE (United States Office of Indian Affairs), Anthropology
M. J. ANDRADE (University of Chicago), Linguistics
E. B. BABCOCK (University of California), Genetics
I. W. BAILEY (Bussey Institute), Plant Biology
J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism
V. BJERKNES (University of Oslo, Norway), Meteorology
G. BREIT (University of Wisconsin), Physics
J. P. BUWALDA (California Institute of Technology), Geology and Palæontology
IAN CAMPBELL (California Institute of Technology), Geology and Palæontology
W. E. CASTLE (University of California), Biology
RALPH W. CHANEY (University of California), Palæobotany
S. CHAPMAN (Imperial College, London), Terrestrial Magnetism
A. H. COMPTON (University of Chicago), Physics
L. S. CRESSMAN (University of Oregon), Archæology
L. R. DICE (University of Michigan), Biology
TH. DOBZHANSKY (California Institute of Technology), Genetics
G. GAMOW (George Washington University), Terrestrial Magnetism
ROSS GUNN (Naval Research Laboratory), Terrestrial Magnetism
W. A. HEIDEL (Wesleyan University), History of Science
NORMAN E. A. HINDE (University of California), Geology
EDGAR B. HOWARD (University of Pennsylvania), Archæology and Palæontology
J. H. JEANS (Royal Society of London), Astronomy
THOMAS H. JOHNSON (Bartol Research Foundation), Physics
REMINGTON KELLOGG (United States National Museum), Palæontology
S. A. KORFF (Bartol Research Foundation), Physics
E. A. LOWE (The Institute for Advanced Study), Palæography
C. L. LUNDELL (University of Michigan), Botany
JOHN H. MAXSON (California Institute of Technology), Geology and Palæontology
EDWIN D. MCKEE (United States National Park Service), Geology and Palæontology
R. A. MILLIKAN (California Institute of Technology), Physics
S. A. MITCHELL (University of Virginia), Astronomy
T. H. MORGAN (California Institute of Technology), Biology
ROBERT REDFIELD (University of Chicago), Anthropology
E. G. RITZMAN (New Hampshire Agricultural Experiment Station), Nutrition
MALCOLM J. ROGERS (The San Diego Museum), Archæology and Palæontology
HENRY A. RUGER (Columbia University), Psychology
G. OSCAR RUSSELL (Ohio State University), Physiology
HENRY N. RUSSELL (Princeton University), Astronomy
A. H. SCHULTZ (Johns Hopkins University), Anthropology
H. C. SHERMAN (Columbia University), Nutrition
JOEL STEBBINS (University of Wisconsin), Astronomy
CHESTER STOCK (California Institute of Technology), Palæontology
H. U. SVERDRUP (Scripps Institute of Oceanography), Terrestrial Magnetism
H. B. VICKERY (Connecticut Agricultural Experiment Station), Physiological Chemistry
G. H. R. VON KOENIGSWALD (Bandoeng, Java), Palæontology
BAILEY WILLIS (Stanford University), Seismology
E. B. WILSON (Harvard University), Climatology

OFFICES OF ADMINISTRATION

January 1, 1939

VANNEVAR BUSH, *President*

Office of the President

VANNEVAR BUSH, *President*

WALTER M. GILBERT, *Administrative Secretary*

SAMUEL CALLAWAY, *President's Secretary*

Office of Publications

FRANK F. BUNKER, *Editor*

IRVING M. GREY, *Secretary*

DOROTHY R. SWIFT, *Editorial Assistant*

Office of the Bursar

EDMUND A. VARELA, *Bursar*

EARLE B. BIESECKER, *Assistant Bursar*

ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a divisional type of organization, representing investigations in plant biology, in animal biology, and in historical research, has been effected in order to make possible a larger degree of unity and closer cooperation. An advisory committee representing the interests of the Institution in the physical sciences facilitates research in that field. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication, both in the form of technical monographs and as news bulletins.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh,

ARTICLES OF INCORPORATION

Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said

ARTICLES OF INCORPORATION

trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, and December 10, 1937

ARTICLE I

THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III

OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V

COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio*

BY-LAWS OF THE INSTITUTION

and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

BY-LAWS OF THE INSTITUTION

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII

AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE THIRTY-NINTH MEETING OF THE BOARD OF TRUSTEES

Upon call of the Executive Committee, and in accordance with instructions of the Board of Trustees at its annual meeting of December 10, 1937, a special meeting of the Board was held in New York City in the offices of the Carnegie Corporation of New York, 522 Fifth Avenue, on Thursday, June 2, 1938. The meeting was called to order at 2:30 p.m. by the Chairman, Mr. Forbes.

Upon roll-call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Stewart Paton, Elihu Root, Jr., Henry R. Shepley, William Benson Storey, Richard P. Strong, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed.

The Chairman reviewed the action of the Board of Trustees taken at its annual meeting on December 10, 1937, calling attention to the election of Dr. John C. Merriam as President Emeritus of the Institution beginning January 1, 1939, and to necessity for selection of a new president.

Mr. Walcott, chairman of the special committee appointed to select a candidate for the presidency, reported that after careful consideration of numerous candidates the committee on nomination had agreed upon the name of Dr. Vannevar Bush, of Massachusetts Institute of Technology, and that Dr. Bush had given consent to have his name presented and had expressed his willingness to accept if elected. Mr. Walcott stated that the nomination of Dr. Bush had also been discussed at the meeting of the Executive Committee immediately preceding the present meeting of the Board with the result that the Executive Committee had voted to recommend favorable action by the Board upon Dr. Bush's nomination.

The Board then proceeded to consider the recommendations of the committee on nomination and of the Executive Committee that Dr. Bush be elected to the presidency. After discussion, as no other nomination than that of Dr. Bush had been offered, the Board proceeded to ballot upon his nomination. It was found that seventeen votes had been cast, all for Dr. Bush, and he was declared unanimously elected to the presidency of the Carnegie Institution of Washington, effective January 1, 1939.

Upon motion of Mr. Hoover, the Executive Committee was asked to prepare expression of the genuine sentiment of the Board with regard to the wide extent and high character of the services of the retiring President, Dr. Merriam.

Upon motion of Mr. Shepley, a vote of appreciation was authorized in recognition of the time and service rendered by the members of the nominating committee, consisting of Mr. Walcott, chairman, Mr. Bell, and Dr. Jewett.

The meeting adjourned at 3:10 p.m.

ABSTRACT OF MINUTES OF THE FORTIETH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 9, 1938. It was called to order by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, Robert Woods Bliss, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Herbert Hoover, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Henry S. Morgan, Stewart Paton, Elihu Root, Jr., Henry R. Shepley, William Benson Storey, Richard P. Strong, Charles P. Taft, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Dr. John C. Merriam, and the President-Elect, Dr. Vannevar Bush, were also in attendance.

An abstract of the minutes of the thirty-ninth meeting, held in New York on June 2, 1938, was read by the Secretary, Mr. Delano, and was approved as printed and distributed to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1939 were authorized:

Pension Fund.....	\$60,000
Administration.....	104,440
Publications (including Office of Publications).....	67,640
Departments and Divisions of Research.....	1,083,211
Minor Grants.....	124,000
General Contingent Fund	60,000
Special Emergency Reserve Fund.....	20,000
	<hr/>
	\$1,519,291

Balloting for a Trustee to fill a vacancy in the Board, caused by the death of Dr. Campbell, resulted in the election of Dr. Walter A. Jessup, President of the Carnegie Foundation* for the Advancement of Teaching.

The resignation of Stewart Paton as a member of the Executive Committee was presented and accepted with regret.

Walter S. Gifford and Frederic C. Walcott were elected to succeed themselves for a period of three years as members of the Executive Committee, and Dr. Walter A. Jessup was elected a member of the Executive Committee to fill the unexpired term of Dr. Paton.

The following resolution was authorized:

RESOLVED, That the Trustees approve the creation of four standing committees of their number to advise with the President concerning the activities of the Institution in the following fields of research: astronomical, terrestrial, biological, historical. These committees shall meet from time to time and, in consultation with the President, shall examine into the activities of the Institution in their respective fields. They shall report their conclusions and recommendations through the Executive Committee to the Board. The Chairman shall appoint these committees annually.

The report of the President was delivered in person.

The President expressed to the Board his personal appreciation of the manner in which it had met his suggestion regarding retirement. He spoke especially of his election as President Emeritus with provision for conduct of his researches, and indicated the importance to him of opportunity for conducting his investigations as President Emeritus in relation to the Institution. He stated that his researches will be taken up again where he has been standing for a long time; that is, with the earlier history of things. He expressed his belief in palæontology as a good foundation on which to build a thinking program, because it begins with questions that touch the eternal verities; and his hope that he may continue to build on this foundation in many directions.

After expressing appreciation of the publications presented to him on occasion of his retirement, the President referred to a series of papers in this collection on the relation of research to education and on the position of the educational institution, the relation of research to the industries, and, later, the relation of the research institution to education, these articles covering a period of over forty years. As result of such study he had no doubt that, so far as the development of fundamental research is concerned, the situation existing in the Carnegie Institution represents the most favorable group of conditions in the world for the advancement of research broadly, and also specifically, provided the various problems are kept in proper relation to one another and emphasis is maintained on the more fundamental aspects of research rather than on the specific applications of investigation.

Reference was made to development of the Institution into groups of agencies, or departments, separated from one another and isolated from the central administration, and the resulting problem of how so to modify the relations as to further these activities in such manner as to permit future flexibility in direction and emphasis of the program as a whole. The effort to have the Institution concern itself with projects, with specific great objectives which might serve as terminal points for certain investigations, has developed and serves to prevent freezing up of money, apparatus, and personnel, and, on the other hand, offers that degree of freedom and mobility which permits the closing out of some things and concentration of attention in other directions.

In contrast to institutionalization through isolation of departments, it was pointed out that there is danger of swinging too far in the other direction by diffusion of small sums widely without adequate guidance, so that, while the money is vouchered properly, there may be small yield in scientific result.

For many years, the President stated, the Institution has been sailing between the Scylla of institutionalization and the Charybdis of the isolated small grant without relation to the departments. He considers it probable that such a situation cannot be avoided; that both types of support must be given; and that there will always be dangers in both.

With reference to the relation between the distinctly research aspect of the Institution's program, in the sense of experimentation and observation, and the interpretative aspect, it was recalled that one of the first results from early exhibitions of the Institution was discovery by some investigators that they could not explain their materials to the visitors easily, and

that this situation, strangely enough, seemed due to lack of clearly organized knowledge of the subjects represented. Further study, however, developed a power of exposition and of interpretation which goes back into the investigation, sometimes by way of interpretation to the scientific public. It was brought out that this problem of interpretation has concerned several things: one is the lay public, and another is the influence upon the investigator. When the Institution initiated its press releases some years ago, it was assumed that they would be interpreting science to the layman, but it was surprising to find that the first reaction came from workers in other scientific fields. It was discovered that research was being interpreted to men in other subjects, which opened a new field, and a new need for interpretation, so that, as time passed, the interpretational aspect of the Institution's program became increasingly important. Some years ago the period of lag between obtaining knowledge and its application was figured at about fifty years; more recent calculations place this lag between twenty-five and thirty years, partly as result of better methods of interpretation.

Reference was made to groups within the Institution studying various kinds of application, but not with the expectation that they will themselves apply the results. The studies have been made with a view to finding ways in which the results could be conveyed to those who are expert in application, making the proper contacts so that the flow of knowledge from research will go easily and quickly to the places where it can be used by those who know, and so that there will be developed a relation between this kind of institution and those agencies controlled by engineers or doctors, or whoever they may be, who are experts in application, so that values are not lost.

Emphasis was laid upon the point that unless there is an enthusiastic group of persons interested in advancing knowledge by the most fundamental research, by the most careful means and the most accurate methods, unless we are standing upon the truth, everything done is useless. If one does not depend fully upon securing the truth and using the best methods, then his assumed facts, his scientific papers, his interpretation through lectures and exhibits will have little value.

The President expressed his belief that the staff of the Institution at the present time is good. The leading men on the staff now have in many instances grown up in the Institution, and it is a splendid thing to build up young men so that they acquire a reputation for their work.

The President declared further that the considerable experience with the Institution which it has been his privilege to have, at the same time following contact with other kinds of agencies and study of still others, has left a clear impression that there is no type of institution which offers greater possibilities for the advance of knowledge through research than the Carnegie Institution, provided always that it holds to the high ideals set up at the beginning and that have been maintained by guidance of the Board of Trustees through these years. Research, in the last analysis, he observed, seems one of the most important things that the world has thought out. It gives us so much that the end cannot yet be seen. The limits of the human mind are not known, but it will be long before men reach a place where research will not be able to produce still more information. The opinion was ex-

pressed that, with careful guidance, this institution will continue to pay large dividends, not merely for decades but for centuries to come.

The Chairman called attention to the action of the Board of Trustees at its special meeting of June 2, 1938, whereby the Executive Committee was asked to prepare expression of genuine sentiment of the Board with regard to the wide extent and high character of the services of the retiring President. The Chairman stated that the foreword to the four volumes of the collected works of Dr. Merriam which have been printed and presented to him express such a tribute. President Merriam commented that there could be no finer tribute than the foreword to these volumes.

The meeting adjourned at 12:35 p. m.

REPORT OF THE EXECUTIVE COMMITTEE

For the Year Ending October 31, 1938

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1938.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

A full statement of the work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. The recommendations of the President in this connection were made after consultation by him on the questions involved with Dr. Vannevar Bush, President-elect of the Institution. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1939, and budget recommendations are based upon judgment of these Committees with respect to financial policy for protection both of capital and of income, and concerning the problem of investment of funds.

The Board of Trustees, at its meeting of December 10, 1937, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1938. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1938, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1938, showing funds available for expenditure and amounts allotted by the Executive Committee, and a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

Construction of the addition to the Administration Building, which is to be used primarily for advancing the public relations program of the Institution, progressed during the past year to a stage at which it was possible to occupy office space in the structure in October, and it is expected that all

details will be completed in advance of initiation of the fall and winter lecture series.

One vacancy exists in the membership of the Board of Trustees, caused by the death of W. W. Campbell on June 14, 1938. Nominations to fill vacancies have been requested, received, and distributed in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 9, 1938.

No vacancies exist among the officers of the Board or in its Committees. Tenures of office of Messrs. Gifford and Walcott as members of the Executive Committee expire at the annual meeting on December 9.

W. CAMERON FORBES, *Chairman*
 ROBERT WOODS BLISS
 FREDERIC A. DELANO
 WALTER S. GIFFORD
 JOHN C. MERRIAM
 STEWART PATON
 FREDERIC C. WALCOTT
 LEWIS H. WEED

November 19, 1938

Financial Statement for Fiscal Year Ending October 31, 1938

	Balances unallotted Oct. 31, 1937	Trustees' appropri- ation Dec. 10, 1937	Revert- ments and transfers Nov. 1, 1937, to Oct. 31, 1938	Total available 1938	Executive Committee allotments 1938	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1938
Large Grants:							
Animal Biology:							
Administrative Expenses.....		\$2,300		\$2,300	\$2,300		
Embryology.....		78,642	\$1,700	80,342	80,342		
Genetics.....		144,645	1,100	145,745	145,745		
Nutrition Laboratory.....		30,000	500	30,500	30,180		\$320
Tortugas Laboratory.....		14,000	1,500	15,500	15,500		
Geophysical Laboratory.....		156,282	6,825	163,107	163,107		
Historical Research.....		152,890	4,800	157,690	157,690		
Mount Wilson Observatory.....		219,530	27,150	246,680	246,680		
Plant Biology.....		96,479	9,025	105,504	105,504		
Terrestrial Magnetism.....		189,310	6,829.22	196,139.22	196,139.22		
Minor Grants.....	\$5,297.06	115,500	33,068.95	153,866.01	144,000.00		9,866.01
Publications.....	55,740.97	97,220	12,454.74	165,415.71	104,195.09		61,220.62
Administration.....		64,550	15,700	80,250	80,250		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund.....	46,028.60	110,000	34,840.64	190,869.33	47,226.28	\$76,129.22	67,513.83
Special Emergency Reserve Fund.....		180,000		180,000	130,000		
	107,066.72	1,661,348	155,493.55	1,923,908.27	1,708,858.59	76,129.22	138,920.46

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1938

RECEIPTS		DISBURSEMENTS	
<i>Interest from Securities and Bank Balances</i>	\$43,917,386.59	<i>Investments (*)</i>	\$67,191,350.35
<i>Colburn Fund</i>	52,015.74	<i>Pension Fund</i>	937,125.34
<i>Sales of Publications</i>	335,756.03	<i>Insurance Fund</i>	120,465.68
<i>Revertments</i>	811,052.00	<i>General Contingent Fund</i>	199,839.94
<i>Pension Fund</i>	81,697.68	<i>Special Emergency Reserve Fund</i>	121,341.19
<i>Insurance Fund</i>	12,283.87	<i>Special Reserve Fund for Administration Bldg. Additions</i>	363,275.93
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i>	17,450.63	<i>Grants</i>	
<i>Redemption and Sale of Bonds</i>	56,644,371.51	<i>Large</i>	\$30,233,616.19
<i>Carnegie Corporation of N. Y.</i>	7,563,581.24	<i>Minor</i>	5,074,449.19
<i>Miscellaneous</i>	6,684.96	<i>Publications</i>	2,571,056.27
	109,442,280.25	<i>National Research Council</i>	150,000.00
		<i>Administration</i>	2,107,082.92
		<i>Cash in Banks</i>	109,069,603.00
			372,677.25
			109,442,280.25

(*) Including Administration Building, \$309,915.69, and Collection Charges.

REPORT OF AUDITORS

TO THE BOARD OF TRUSTEES

*Carnegie Institution of Washington
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1938.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were either verified by inspection or by certificates received from depositaries and custodians. As in the past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost or value at date acquired, this being the established custom of the Institution. Real estate and equipment are stated at original cost and books on hand for sale at their sales prices.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying Balance Sheet, statement of Receipts and Disbursements and detailed Schedule of Securities properly present the financial position of the CARNEGIE INSTITUTION OF WASHINGTON at October 31, 1938 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY
Accountants and Auditors

New York, N. Y., November 28, 1938

Receipts and Disbursements for Year Ending October 31, 1938

RECEIPTS		DISBURSEMENTS	
<i>Interest and Dividends from Securities</i>		<i>Investments</i>	\$3,612,567.91
<i>Sales of Publications</i>		<i>Securities</i>	21,278.00
<i>Index Medicus</i>	\$109.50	<i>Accrued interest purchased</i>	\$3,633,845.91
<i>Year Book</i>	94.80		
<i>Miscellaneous Books</i>	4,866.75	<i>Pension Fund</i>	71,720.69
		<i>Insurance Fund</i>	6,141.00
<i>Reverments</i>		<i>General Contingent Fund</i>	34,176.46
<i>Large Grants</i>	4,951.20	<i>Special Emergency Reserve Fund</i>	50.05
<i>Departments</i>	3,425.00	<i>Special Reserve Fund for Administra-</i>	346,155.91
<i>Contributions</i>	10,333.24	<i>tion Building Additions</i>	
<i>National Research Council</i>	2,750.00	<i>Grants</i>	
<i>California Institute of Tech-</i>	8,500.00	<i>Large</i>	1,209,365.94
<i>nology</i>	30,709.44	<i>Minor</i>	118,797.98
<i>International Cancer Research</i>		<i>Publication</i>	
<i>Foundation</i>		<i>General Publication</i>	79,263.15
<i>Geological Society of America</i>		<i>Catalogues, Advertising, etc.</i>	1,202.72
<i>Rockefeller Foundation</i>		<i>Shipping Expenses</i>	7,202.99
		<i>Office of Publications</i>	24,846.67
		<i>Administration</i>	
<i>Minor Grants</i>	1,797.26	<i>Trustees</i>	2,540.22
<i>Publication</i>	1,582.48	<i>Executive Committee</i>	3,487.03
<i>Administration</i>	1,533.91	<i>Salaries</i>	45,912.49
<i>Unappropriated Fund</i>	400.36	<i>Surety, postage, tel. and tel.</i>	2,250.01
<i>General Contingent Fund</i>	46.32	<i>Printing, paper</i>	932.25
		<i>Office expenses</i>	2,672.83
<i>Pension Fund</i>		<i>Legal Services</i>	1,000.00
<i>Insurance Fund</i>		<i>Investment Office</i>	7,632.17
<i>Special Reserve Fund for Administra-</i>		<i>Equipment</i>	71.65
<i>tion Building Additions (Rentals)</i>		<i>Building, maintenance</i>	4,955.03
<i>Redemption and Sale of Securities</i>		<i>Lectures and Exhibits</i>	1,698.71
<i>Carnegie Corporation of N. Y.</i>			73,152.39
		<i>Cash in Banks, October 31, 1938</i>	5,605,921.86
		<i>Uninvested Principal</i>	
		<i>Awaiting investment</i>	9,946.32
		<i>Reserved for current needs</i>	74,724.52
		<i>Income Account</i>	84,670.84
<i>Balance in Banks, October 31, 1937</i>			288,006.41
			372,677.25
			5,978,599.11

Schedule of Securities

Aggregate Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Railways</i>					
\$500,000	A. T. & S. Fe 1st & ref. 4½s			1962	M-S	\$498,750.
43,000	A. T. & S. Fe Conv. 4s			1955	J-D	39,022.50
50,000	A. T. & S. Fe gen. 4s	*		1995	A-O	50,056.25
50,000	Balto. & Ohio R. R. ref. 4s			1941	M-N	46,875.
100,000	Balto. & Ohio R. R. 1st Mtg. 5s	*		1948	JAJO	105,500.
100,000	Balto. & Ohio R. R. gen. and ref. 5s	*		1995	J-D	102,416.67
50,000	Balto. & Ohio R. R. gen. and ref. 5s			1996	M-S	30,307.50
27,000	Boston & Maine R. R. Co. 1st Mtg. 4½s			1961	A-O	7,163.22
176,000	Boston & Maine 1st 5s			1967	M-S	151,137.64
100,000	Canadian National Ry. Co. 5s			1969	J-J	98,500.
100,000	Canadian National Ry. Co. 4½s			1957	J-J	112,000.
160,000	Canadian Pac. Col. Trust 5s			1954	J-D	159,710.07
50,000	Canada Southern Ry. Co. con. 5s			1962	A-O	49,021.50
175,000	Ches. & Ohio Ry. gen. 4½s			1992	M-S	174,062.50
100,000	Ches. & Ohio Ry. Eq. Tr. Series 1929 4½s			1939-40	M-N	96,825.50
50,000	Central Pac. Ry. 1st ref. 4s	*		1949	F-A	48,250.
100,000	Chicago B. & Q. R. R. III. Div. 3½s			1949	J-J	93,099.87
180,000	Chicago B. & Q. R. R. gen. 4s	*		1958	M-S	169,501.25
100,000	Chicago B. & Q. R. R. III. Div. 4s	*		1949	J-J	97,750.
35,000	Chicago M. St. P. & P. 5s			1975	F-A	31,853.50
189,000	Chicago Ind. & L. 1st & gen. 5s			1966	M-N	189,461.25
140,000	Chicago M. St. P. & P. conv. adj. 5s			2000	A-O	127,414.50
234,000	Chicago M. & St. P. Ry. gen. 4½s (\$5,000 fully reg., \$29,000 reg. princ.)	*	*	1989	J-J	227,162.50
120,000	Chicago & N. W. Ry. gen. 3½s	*		1987	FMAN	100,306.
200,000	Chicago & N. W. Ry. gen. 4½s			1987	M-N	210,000.
300,000	Chicago, R. I. & P. Ry. 4½s			1952	M-S	280,964.50
50,000	Chicago Union Station Co. 1st Mtg. 3½s			1963	J-J	52,125.
150,000	Chicago & W. Indiana R. R. Co., cons. 4s			1952	J-J	140,715.27
50,000	Clev. C. C. & St. Louis Ry., 1st 4s			1939	J-J	45,500.
100,000	Clev. C. C. & St. Louis Ry., ref. and imp. 4½s			1977	J-J	99,272.50
100,000	Clev. C. C. & St. Louis Ry. gen. 4s			1993	J-D	78,906.25
300,000	Elgin, Joliet & E. Ry. Co., 5s			1941	M-N	107,125.
90,000	Erie R. R. gen. 4s			1996	J-J	242,937.50
69,000	Erie R. R. Eq. Trust 4½s			1942-43	J-D	86,467.90
117,000	Great Northern Ry. 1st ref. 4½s	*		1961	J-J	89,053.25
173,000	Great Northern Ry. gen. 5s			1977	J-J	114,806.25
300,000	Ill. Cent. R. R. Joint 5s			1973	J-D	180,587.50
121,000	Ill. Cent. R. R. ref. 4s	*		1963	J-D	311,291.50
120,000	Ill. Cent. R. R. ref. 4s			1955	M-N	108,677.50
150,000	Ill. Cent. Eq. Trust 4½s			1942-44	A-O	115,184.84
200,000	Kan. City Term. 1st 4s			1960	J-J	134,796.57
	Kan. City, F. S. & M. Ry. ref. 4s (Certificate of Deposit)			1936	A-O	187,250.
225,000	Lehigh & L. E. 4½s	*		1957	M-S	229,547.29
100,000	Lehigh V. H. Term. Ry. 1st 5s			1954	F-A	104,750.
50,000	Long Island ref. 4s	*		1949	M-S	48,285.
250,000	Louisville & N. R. R. 1st & ref. 4½s			2003	A-O	249,125.
100,000	Mo. Kan. & T. 1st 4s		*	1990	J-D	82,068.13
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s			1977	M-S	212,762.50
200,000	Mo. Pac. R. R. Eq. Trust 4½s			1939-42	M-N	192,206.79
150,000	Mobile and O. R. R. ref. and imp. 4½s (Certificate of Deposit)			1977	M-S	145,750.
186,000	N. Y. Cent. R. R. ref. & imp. 4½s			2013	A-O	87,663.45
5,000	N. Y. Cent. R. R. ref. & imp. 5s			2013	A-O	2,556.25
55,000	New York, Chicago & St. L. R. R. Co., ref. mtg. 4½s			1978	M-S	51,536.25
50,000	New York, Penna. & Ohio R. R. 4½s			1950	M-S	52,500.
50,000	N. Y. W. and Boston 1st 4½s	*		1946	J-J	49,187.50
150,000	Northern Pacific ref. and imp. 0s			2047	J-J	150,450.
50,000	Northern Pacific gen. lien 3s	*		2047	FMAN	33,101.25
51,000	Oregon Short Line con. 5s			1946	J-J	49,373.25
310,000	Oregon Wash. R. & N. 1st ref. 4s (\$50,000 fully registered)	*		1961	J-J	274,272.50
80,000	Penna. R. R. Co. gen. 4½s	*		1965	J-D	80,900.
125,000	Penna. R. R. Co. con. 4½s	*		1960	F-A	130,703.13
50,000	Pere Marquette Ry. Co. 1st Mtg. 5s			1956	J-J	44,282.50
300,000	Pitts. C. C. & St. L. 5s			1975	A-O	311,393.75
42,000	Pitts. Shawmut & Nor. 4s (Ctf. Dep.)	*		1952	J-J	4,200.
125,000	So. Pac. 1st ref. 4s (\$100,000 fully reg.)	*		1955	J-J	116,617.50
200,000	So. Pac. conv. 4½s			1969	M-N	180,000.
350,000	Southern Rwy. Co. 1st con. 5s			1994	J-J	362,531.25
225,000	St. Louis-S. F., prior lien 4s (Ctf. Dep.)			1950	J-J	203,431.25
32,000	Term. R. R. Assn. of St. Louis 1st Mtg. 4½s			1939	A-O	30,400.
162,000	Term. R. R. Assn. of St. Louis 4s			1953	J-J	147,197.60
210,000	Texas & Pac. Ry., gen. and ref. 5s			1977	A-O	213,882.50
100,000	Toledo & Ohio Central Ry. Co. ref. & imp. 3½s			1960	J-D	99,000.
2,084,000	Union R. R. deb. 6s	*		1946	J-D	2,084,000.
140,000	Unifon Pac. 1st lien and ref. 4s	*		2008	M-S	128,722.50
150,000	Virginian Ry. Co. 1st Lien & ref. 3½s			1966	M-S	153,375.
40,000	Wabash R. R. Co., 1st 5s			1939	M-N	37,750.
200,000	Wabash Ry. ref. and gen. 5s			1976	F-A	203,250.
100,000	West Shore R. R. Co., 1st Mtg. 4s	*		2361	J-J	78,140.
200,000	Western Md. R. R. 1st & Ref. Mtg. 5½s			1977	J-J	170,708.75
12,729,000	Railway Sub-Total					12,167,958.44

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Duc	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility</i>					
\$100,000	Ala. Power Co. 1st & ref. 4½s.			1967	J-D	\$87,265.
212,000	Ala. Power Co. 1st & ref. 5s.			1968	M-S	202,322.50
175,000	Am. Tel. & Tel. Co. deb. 3½s.			1961	A-O	176,750.
190,000	Am. Tel. & Tel. Co. deb. 3½s.			1966	J-D	193,800.
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s.			1943	M-N	130,260.62
300,000	Appalachian Electric Power Co. 1st Mtg. 4s			1963	F-A	296,250.
300,000	Ark. P. & L. Co. 5s.			1956	A-O	292,312.50
56,000	Bell Tel. Co. of Canada 1st 5s.			1955	M-S	57,715.
100,000	Bell Tel. Co. of Canada 1st 5s.			1957	J-D	101,125.
300,000	Birmingham Electric Co., 1st ref. 4½s.			1968	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 4s.			1965	M-N	76,875.
300,000	Carolina Power & L. Co. 1st & ref. 5s.			1956	A-O	302,298.75
110,000	Cedar R. Mfg. & P. Co. 1st sink. 5s.			1953	J-J	109,560.50
380,000	Columbia Gas and Elec. Corp., deb. 5s.			1961	J-J	379,782.50
300,000	Columbus Rwy. P. & L. 4s.			1965	M-N	304,500.
23,900	Commonwealth Edison Co. Conv. 3½s.			1958	J-J	23,910.75
83,000	Commonwealth Edison Co. 1st Mtg. 3½s.			1968	J-D	85,712.87
158,000	Commonwealth Edison Co. 1st Mtg. 4s.			1981	M-S	115,465.49
50,000	Consolidated Edison Co. of N.Y. deb. 3½s.			1948	A-O	50,875.
40,000	Consolidated Edison Co. of N.Y. deb. 3½s.			1958	J-J	40,730.
100,000	Detroit Edison gen. & ref. 4s.			1965	A-O	103,500.
250,000	Gatineau Power, 1st 5s.			1956	J-D	248,958.33
325,000	Georgia Power Co. 1st ref. 5s.			1967	M-S	320,112.50
200,000	Gulf States Util. Co. 1st Mtg. & ref. 4s.			1966	A-O	206,000.
90,000	Hackensack Water Co., Gen. & Ref. 5½s.			1977	J-J	97,243.75
25,000	Houston Ltg. & Power Co. 1st mtg. 3½s.			1966	J-D	25,750.
200,000	Illinois P. & L., 1st & ref. 5s.			1956	J-D	196,750.
173,000	Indianapolis P. & L. 1st 3½s.			1968	F-A	173,000.
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s.			1955	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½s.			1952	J-J	288,250.
280,000	Interborough Rap. Trans. ref. 5s.	*		1966	J-J	276,701.
100,000	Iowa Southern Utilities Co. 1st & ref. 5½s.			1950	M-N	100,474.66
150,000	Louisiana Power & Light Co., 1st 5s.			1957	J-D	154,900.
300,000	Memphis P. & L. 1st & ref. 4½s.			1978	A-O	270,250.
100,000	Metropolitan Edison Co. 1st 4½s.			1968	M-S	100,470.
100,000	Minnesota P. & L. 1st & ref. 4½s.			1978	M-N	92,156.25
50,000	Monongahela West Penn. Pub. Serv. Co. 1st & gen. 4½s.			1960	A-O	52,000.
100,000	Montana Power Co., 1st & Ref. 3½s.			1966	J-D	101,000.
25,000	Mountain States Tel. & Tel. Co. Deb. 3½s.			1968	J-D	25,500.
52,000	New Eng. Tel. & Tel. 5s.			1952	J-D	51,748.
100,000	New Orleans Pub. S. 5s.			1955	J-D	99,200.
65,000	New York & Westchester Ltg. 5s.			1954	J-J	67,052.50
300,000	New York P. & L., 1st 4½s.			1967	A-O	286,125.
150,000	Northern Ind. Pub. S., 1st ref. 5s.			1966	M-N	152,887.50
50,000	Northern States Power Co., 1st & Ref. 3½s.			1967	F-A	47,500.
100,000	Ohio Edison Co. 1st Mtg. 4s.			1967	M-S	100,266.25
100,000	Ohio Power Co. 1st 3½s.			1968	A-O	101,500.
175,000	Ohio Power Co., 1st and ref. 4½s.			1956	J-D	163,439.06
100,000	Ohio Public Serv. Co., 1st Mtg. 4s.			1962	F-A	102,625.
200,000	Okla. G. & E. 1st 3½s.			1966	J-D	205,000.
100,000	Oklahoma Natural Gas Co. 1st Mtg. 4½s.			1951	M-N	99,500.
100,000	Pac. G. & E. Co., 1st & ref. 3½s.			1961	J-D	102,500.
100,000	Pac. G. & E. Co., 1st & ref. 4s.			1964	J-D	104,000.
200,000	Penn. Electric Co., 1st & Ref. 5s.			1962	A-O	203,882.50
300,000	Penn. Power & L. Co., 1st mtg. 4½s.			1981	A-O	289,562.50
105,000	Penn. Water & Power Co., 1st ref. 4½s.			1968	M-S	102,597.06
136,000	Pub. Serv. Co. of Indiana, 1st & ref. 6s.			1952	F-A	112,540.
141,000	Pub. Serv. Co. of No. Ill., 1st Mtg. 3½s.			1968	A-O	145,230.
70,000	Pub. Serv. Co. of No. Ill. 1st Lien & Ref. 4½s.			1981	A-O	66,655.
60,000	Puget Sound Power & L. 1st & Ref. 4½s.			1950	J-D	58,550.
50,000	Puget Sound Power & L. 1st & ref. 5½s.			1949	J-D	31,900.
75,000	Rochester Gas & Elec. Corp. gen. 5s.			1962	M-S	69,475.
250,000	Shawinigan Water & Power Co., 1st & coll. 4½s.			1967	A-O	238,510.42
75,000	Southern Bell Tel. & Tel. Co. Deb. 3½s.			1962	A-O	72,375.
200,000	So. Calif. Edison Co., 1st & ref. 3½s.			1960	J-J	197,000.
125,000	Tenn. E. & P. 1st & ref. 5s.			1956	J-D	127,037.50
300,000	Texas Electric Service 5s.			1960	J-J	292,700.
200,000	Texas Power & Light Co. 1st & ref. 5s.			1956	M-N	205,143.75
120,000	Toledo Edison 1st Mtg. 3½s.			1968	J-J	121,800.
250,000	Union Elec. Co. of Missouri, 1st Coll. Trust 3½s.			1962	J-J	249,537.50
220,000	Utah L. & T. Co., ref. 5s.			1944	A-O	215,193.
263,000	Virginia Elec. & Power Co. 1st & ref. 3½s.			1968	M-S	272,205.
235,000	Washington Water Power Co., 1st & gen. mtg. 5s.			1960	J-J	237,496.87
100,000	Western United Gas & Electric Co., 1st Mtg. 5½s.			1955	J-D	105,187.50
213,000	Wisconsin Electric Power Co. 1st 3½s.			1968	A-O	220,455.
11,825,900	Public Utility Sub-Total					11,680,123.63

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
Mortgages						
\$25,000	Empire Title and Guaranty Co., Guar. 1st Mtg., Ctf. No. 1676 5%.....	*	.....	1939	FMAN	\$25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Ctfs., Series 18397 5½%.....	*	.....	1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½% Mortgage.....	*	.....	1935	A-O	80,000.
98,250	Lawyers Title and Guaranty Co., Guar- anteed 1st Mortgage 4½%.....	*	.....	1942	J-J	97,758.75
100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. 4%.....	*	.....	1940	MJSD	100,000.00
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5½%.....	*	.....	1938	J-D	90,000.
99,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. 4½%.....	*	.....	1940	J-D	99,000.
100,000	Title Guarantee and Trust Co. 1st Mtg. Ctf. 180057 3% Participating.....	*	.....	1939	J-D	100,000.
692,250	Mortgages Sub-Total.....	.....	.....	.....	.....	691,758.75
Industrial						
25,000	Addressograph-Multigraph Corp. Deb. 5½s.....	.....	.....	1945	A-O	25,000.
50,000	Allis-Chalmers Mfg. Co., Conv. Deb. 4s.....	.....	.....	1952	M-S	51,587.
100,000	American I. G. Chemical Corp., conv. 5½s.....	.....	.....	1949	M-N	105,861.25
50,000	American Radiator Co., Deb. 4½s.....	.....	.....	1947	M-N	49,125.
99,000	Bethlehem Steel Corp. Cons. sink. fund 4½s.....	.....	.....	1960	J-J	97,515.
6,000	Phelps Dodge Corp. Conv. Deb. 3½s.....	.....	.....	1952	J-D	6,000.
200,000	Rwy. Express Agency, 5s.....	.....	.....	1939-48	M-S	200,000.
100,000	Remington Rand, Inc., Deb. 4½s.....	.....	.....	1956	M-S	100,162.50
94,000	Scovill Manufacturing Co., Conv. Deb. 5½s.....	.....	.....	1945	J-J	96,747.66
250,000	Shell Union Oil Corp., Deb. 3½s.....	.....	.....	1951	M-S	247,500.
100,000	Sooony Vacuum Oil Co. Deb. 3½s.....	.....	.....	1950	A-O	100,000.
53,000	Southern Kraft Corp., 1st leasehold & gen. mtg. 4½s.....	.....	.....	1946	J-D	51,790.
100,000	Standard Oil Co. of N. J. Deb. 2½s.....	.....	.....	1953	J-J	99,000.
1,925,000	Tenn. C. I. & R. Co. 5s.....	.....	.....	1951	J-J	1,925,000.
100,000	Texas Corp., Deb. 3½s.....	.....	.....	1951	J-D	100,000.
100,000	United States Steel Corp. Deb. 3½s.....	.....	.....	1948	J-D	100,000.
85,000	Wheeling Steel Corp. 1st Mtg. 4½s.....	.....	.....	1966	F-A	86,275.
100,000	Youngstown S. & Tube 1st Mtg. sink. 4s.....	.....	.....	1961	M-N	98,500.
3,537,000	Industrial Sub-Total.....	.....	.....	.....	.....	3,540,063.41
Foreign						
\$ 55,000	Canada, Dom. of 5s.....	.....	.....	1952	M-N	60,450.00
120,500	German External Loan of 1924 7s.....	.....	.....	1949	A-O	128,738.53
40,000	Imp. Japanese Govt. 5½s.....	.....	.....	1965	M-N	35,900.
196,000	Kingdom of Denmark, ext. 4½s.....	.....	.....	1962	A-O	179,258.34
25,000	City of Montreal 5s.....	.....	.....	1956	M-N	24,062.50
75,000	City of Montreal sink. 5s.....	.....	.....	1954	M-N	72,375.
100,000	City of Montreal 4½s.....	.....	.....	1946	F-A	94,368.90
163,000	New South Wales, ext. 5s.....	.....	.....	1958	A-O	154,493.44
100,000	Province of Alberta deb. 4½s.....	.....	.....	1958	J-J	93,750.
100,000	Province of Alberta 5s.....	.....	.....	1950	A-O	101,150.
200,000	Province of Manitoba deb. 4½s.....	.....	.....	1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s.....	.....	.....	1952	M-S	100,312.50
100,000	Province of Ontario 4s.....	.....	.....	1964	M-N	87,150.10
40,000	Province of Ontario 6s.....	.....	.....	1943	M-S	43,137.50
100,000	City of Toronto con. deb. 5s.....	.....	.....	1949	J-D	96,164.59
90,000	City of Toronto, 5s.....	.....	.....	1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s.....	.....	.....	1943	J-D	48,250.
100,000	City of Winnipeg deb. 4½s.....	.....	.....	1946	J-D	95,375.
1,754,500	Foreign Sub-Total.....	.....	.....	.....	.....	1,694,785.63
State and Municipal						
50,000	City of Cleveland, Water Works, 5½s.....	.....	.....	1967	M-N	52,984.60
25,000	City of Detroit, Water Supply, 4s.....	.....	.....	1955	J-D	24,812.50
25,000	City of Detroit, Water Supply, 4½s.....	.....	.....	1952	M-S	25,250.
50,000	City of Newark, Street Opening, 5½s.....	.....	.....	1958	F-A	51,724.94
100,000	City of New York, 4½s.....	.....	.....	1957	M-N	117,062.50
84,000	State of North Carolina, Highway, 4½s (\$30,000 registered).....	*	.....	1953-63	J-J	92,819.50
50,000	City and County of San Francisco, Hetch Hetchy, 5½s.....	.....	.....	1960	J-D	53,523.34
384,000	State and Municipal Sub-Total.....	.....	.....	.....	.....	418,177.38
30,922,650	Bonds—Funds Invested.....	.....	.....	.....	.....	30,192,867.24

Schedule of Securities—Continued

Number of Shares	Description	Total Cost or Value at Date Acquired
<i>Common Stocks</i>		
1,100	Air Reduction Company.....	\$74,647.
1,113	Allis-Chalmers Manufacturing Co.....	55,667.50
700	Alpha Portland Cement Co.....	24,530.
330	American Brake Shoe and Foundry Co.....	15,895.
1,500	American Cyanamid Co.....	46,922.50
2,800	American Radiator & Standard Sanitary Corp.....	67,542.50
1,500	Bethlehem Steel Corp.....	117,325.
2,600	Borg Warner Corp.....	102,642.50
1,300	Caterpillar Tractor Co.....	102,472.
1,100	Chrysler Corporation.....	123,570.50
1,300	Commercial Investment Trust Corp.....	85,247.50
400	Consolidated Edison Co., of N. Y.....	18,335.
800	Continental Can Co.....	46,943.50
708	Continental Insurance Co.....	26,691.30
2,300	Continental Oil Corp.....	83,732.50
900	Deere & Company.....	19,793.50
400	Dow Chemical Co.....	47,194.
500	Eastman Kodak Co.....	82,460.
1,800	General Electric Co.....	63,492.
1,800	General Motors Corporation.....	114,035.50
1,100	W. T. Grant Co.....	37,734.74
1,100	Gulf Oil Corp.....	55,588.26
300	Hartford Fire Insurance Co.....	22,074.68
600	Humble Oil & Refining Co.....	39,167.50
300	Ingersoll-Rand Company.....	29,666.
720	Inland Steel Company.....	75,010.
420.25	International Business Machines Corp.....	64,459.
1,300	International Harvester Co.....	122,972.50
1,900	International Nickel Co.....	110,434.
413	Johns-Manville Corp.....	53,925.
1,900	Kennecott Copper Corp.....	94,155.
900	Monsanto Chemical Co.....	84,036.
1,230	Montgomery Ward & Co.....	72,223.63
400	Mortbon Corp. of N. Y.....	.....
1,500	National Lead Co.....	30,598.
900	Newberry Co. (J. J.).....	50,206.
1,000	New Jersey Zinc Co.....	79,615.
1,000	Owens-Illinois Glass Co.....	73,887.
1,200	Pennney Co. (J. C.).....	117,197.50
1,600	Phelps Dodge Corp.....	64,995.
500	Pittsburgh Plate Glass Co.....	64,340.25
500	Procter & Gamble Co.....	28,112.50
700	Pullman, Inc.....	41,972.50
1,000	St. Joseph Lead Co.....	57,662.50
1,290	Sears Roebuck & Co.....	106,337.50
800	Sherwin-Williams Co.....	85,129.47
1,600	Standard Oil Co., of California.....	69,165.
2,200	Standard Oil Co. of N. J.....	139,796.
2,000	Texas Corporation.....	95,588.26
100	Travelers Insurance Co.....	50,071.21
800	Underwood Elliott Fisher Co.....	62,592.50
1,500	Union Carbide & Carbon Co.....	135,711.50
1,000	United States Gypsum Co.....	104,184.
900	United States Steel Corp.....	92,360.
300	Westinghouse Air Brake Co.....	12,587.75
600	Westinghouse Electric & Mfg. Co.....	70,572.
500	Woolworth Co. (F. W.).....	22,385.
1,520	Youngstown Sheet & Tube Co.....	108,879.75
62,544.25	Common Stocks—Sub-Total.....	3,973,431.80
<i>Preferred Stocks</i>		
120	American Cyanamid Co.....	1,230.
500	A. T. & S. Fe pref. stock.....	52,125.
67	Caterpillar Tractor Co., Cum. pref.....	6,772.
2,000	Cons. Edison Co. Cum. pref. stock.....	198,725.
1,000	Du Pont de Nemours, deb. Stock.....	116,125.
500	J. I. Case Thresh. M. Co. pref. stock.....	62,225.
225	Grant Co. (W. T.).....	7,642.78
1,000	Northern States Power Co., Cum. pref.....	103,000.
400	Union Pac. R. R. pref. stock.....	33,415.
5,000	U. S. Steel Corp., pref. stock.....	715,173.50
10,812	Preferred Stocks—Sub-Total.....	1,296,433.26
73,356.25	Common and Preferred Stocks—Funds Invested.....	5,269,865.06
	Aggregate Investments (Bonds and Stocks).....	35,462,732.30

Real Estate and Equipment, Original Cost

Administration (October 31, 1938)

Washington, D. C.

Building, site, and equipment.....		\$756,544.44
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Division of Plant Biology (September 30, 1938)

Palo Alto, California (Headquarters)

Buildings and grounds.....	\$154,941.86	
Laboratory.....	56,205.20	
Library.....	30,126.77	
Operating appliances.....	25,863.37	267,137.20

Department of Embryology (September 30, 1938)

Wolfe and Madison Sts., Baltimore, Maryland

Library.....	3,574.00	
Laboratory.....	14,540.76	
Administration.....	7,383.53	25,498.29

Department of Genetics (September 30, 1938)

Cold Spring Harbor, Long Island, New York

Buildings, grounds, field.....	292,433.55	
Operating.....	32,097.30	
Laboratory apparatus.....	30,856.52	
Library.....	47,182.74	
Archives.....	45,488.90	448,059.01

Geophysical Laboratory (September 30, 1938)

Upton St., Washington, D. C.

Building, library, operating appliances.....	227,121.91	
Laboratory apparatus.....	161,086.29	
Shop equipment.....	19,508.95	407,717.15

Division of Historical Research (September 30, 1938)

Administration Building, Washington, D. C.

Operating.....	24,556.60	
Library.....	8,497.21	33,053.81

Tortugas Laboratory (September 30, 1938)

Tortugas, Florida

Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,930.86	
Apparatus and instruments.....	9,322.55	53,183.84

Department of Meridian Astrometry (September 30, 1938)

Dudley Observatory, Albany, New York

Apparatus and instruments.....	4,846.84	
Operating.....	5,273.68	10,120.52

Nutrition Laboratory (September 30, 1938)

Vila St., Boston, Massachusetts

Building, office, shop, and library.....	133,887.27	
Laboratory apparatus.....	37,116.14	171,003.41

Mount Wilson Observatory (September 30, 1938)

Pasadena, California

Buildings, grounds, road, and telephone line.....	222,688.94	
Shop equipment.....	45,024.88	
Instruments.....	669,383.19	
Furniture and operating appliances.....	139,492.64	
Hooker 100-inch reflector.....	627,149.01	1,703,738.66

Department of Terrestrial Magnetism (September 30, 1938)

6241 Broad Branch Road, Washington, D. C.

Building, site, and office.....	231,072.72	
Survey equipment.....	101,904.01	
Instruments, laboratory, and shop equipment.....	220,980.50	553,957.23

4,430,013.56

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1938

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

In accordance with regular procedure, the President has the honor to transmit to the Trustees of Carnegie Institution of Washington the following report concerning problems and activities relating to work of the Institution in the year ending October 31, 1938.

Success in any great enterprise calls for such statement of objectives as can be presented in generally intelligible form. In practical operation, any large project develops many collateral purposes in such ways as may confuse the issues unless care is taken to keep major objectives in view. It is also to be expected that with change of conditions as to time, place, and personnel, adjustment will be necessary if the main purposes are to be followed. But somewhere it is essential that there be always such awareness concerning the situation as may prevent misguidance and distortion.

**Relation
between
Research and
Organization
of Knowledge**

In founding the Carnegie Institution an agency was set up in which the purposes were deliberately so defined as to present a set of objectives quite different from those of well known types of organization. And with this action there arose need for intensive study of the opportunity by all selected officers and those concerned with success of the project. The general purposes of the Institution as an agency devoted to "investigation, research, and discovery, and the application of knowledge to the improvement of mankind," as defined by the Founder, conveyed

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an idea of the objectives in a form intelligible to all. But, just as in institutions devoted to higher education there was much discussion as to means by which the defined goals might be attained, so here, there has been natural and proper consideration of means by which ideals of this Institution could be realized.

Research of the constructive or creative or inventive type covers a vast range of subjects and can be conducted in a great variety of ways. Application of the results "to the improvement of mankind" can be viewed again as presenting a multitude of possibilities. To those who organized the beginnings of this great work the opportunities seemed almost limitless. Most wisely they safeguarded the program by insisting upon several principles which were evidently in the mind of the Founder. One of these concerned *quality* of projects, of persons involved, and of materials made available for programs or projects; a second general requirement expressed the need of striving for attainment of what is *fundamental* as, over the years, the best means of advancing knowledge. With reference to application of results, the statement regarding "improvement of mankind" seemed clearly to envisage a process of advancing development of mankind, in which work of the Institution would be contributing to those more fundamental aspects of life out of which improvement grows or is built. So, among his last utterances on these subjects, Elihu Root voiced the hope for such continuing absorption of the results in advance of knowledge into the thought of the people as would permit building to higher and higher levels of thought, appreciation, and belief.

Among the problems necessarily involved in the program of an institution of this nature, one of the most fundamental concerns the relation between that form of intensive investigational activity commonly thought of as representing research, and the type of constructive activity known as organization of knowledge. We know well the contributions of constructive or creative work reaching into fields of the unknown and making new materials available. Organization of knowledge is recognized as opening visions of the whole field, and sometimes leading to such glimpsing of relations between areas of knowledge as makes possible the formulation of great generalizations or principles. The first activity has been recognized as contributing enormously to increase of information; the second is seen to give acquaintance with relationships or principles which are among the greatest values in knowledge.

Depending upon the importance of factors having special significance at a given time, knowledge may seem to be advancing either by reason of particular intensive researches, or because of emphasis on newly developed organization of information. Unless the whole field of learning be examined with reference to all of the types of creative work, it would be easy for difference of opinion to develop concerning the activities through which the more significant advances are made.

From one point of view, it would be possible to indicate that the degree of intensiveness of research in limited fields determines the rate of progress. If this were true, it might be desirable to organize investigational programs in such a manner that emphasis would be placed mainly on concentrated attack upon limited problems, in the hope

that through such effort the whole range of knowledge would, in time, be furthered most effectively.

On the other hand, argument might be made that unless the results coming out of intensive research are related to comparable materials from other fields a very large part of all that could be known through the interlocking of contributions might never appear. Argument might also be made in favor of the view that it is the clear vision of knowledge organized with reference to particular problems that gives us the principles which become the foundations upon which research is built. So, in the field of biology, the general law of evolution is a type of idea which has given tremendous stimulus to study of life in practically every realm. Or, in the inanimate world, the law of gravitation is a foundation upon which much of research on the visible universe must stand.

Experience in many kinds of institutions concerned with research, and with knowledge broadly, indicates that the most effective organization, and the most economical scheme of operation, is one in which there is careful balance between activities devoted to intensive or concentrated research and those giving vision over larger areas, covered in such manner as to obtain the major generalizations coming out of special activities, as also the largest values from the individual researches.

It is true that the term "proper balance" will necessarily be defined according to conditions at a particular period or place. And as these conditions vary the emphasis on different parts of the system will be modified to advantage. It is also true that the question of balance, and in some ways of the wider and deeper perspective involved, has greatest significance in connection with in-

stitutions which represent a considerable variety of subjects.

Realizing that the significance of perspective is most clearly appreciated where the spread of subjects or activities is wide, it is important to keep in mind the fact that in the areas of research covered by the Carnegie Institution of Washington the range of interests extends from the most intimate details of atomic physics out through chemistry, biology, and history up to the threshold of investigations directed more particularly at inquiry concerning human life and activities.

It is interesting to note in this connection that at various times in the history of science, and of philosophy, and also of religion, there have developed definite expressions of the idea of unity, including everything in the physical and biological universe, not only in space but through time. As knowledge advances, this idea of unity becomes in the scientific sense an increasingly practical feature of research on the organization of knowledge. It is no longer possible to study the broader problems of astronomy and the universe without recognition of an interrelation among the elements of the world about us wherever we touch them. In the same manner it is discovered that study of events in geological history, even for remote periods, is based upon application of principles which extend through time, and may be carefully examined in the world today. Again, in consideration of the problem of development of life or evolution, investigation of the various stages in the process is based upon the idea of growth through the years in materials which have a continuity and are, so far as we know, affected in comparable ways by influences through space and time.

In attempting to reach an adequate understanding of relations between widely separated types of researches it invariably becomes important to have each and all of the problems involved stated in such manner that the essential elements are intelligible to investigators interested in determining the connection or relation among these various aspects of nature. Results from the most intensive research will commonly and naturally be expressed in terms of formulæ and shorthand methods, developed in order to permit the investigators to work rapidly and exactly, without the limitations imposed by long and perhaps complicated statements or explanations. Frequently these formulæ are not understood by investigators in other fields, and it becomes important to find some means by which the essential elements of the contributions can be made available to others.

There is much difference of opinion as to how interpretation of basic scientific data may best proceed. Sometimes it is accomplished by what may be called a matter-of-fact statement, which gives details that can be defended from the point of view of the investigator, but which has no vital meaning to students of other problems or of human interests widely. Sometimes it is possible to look into deep reaches of a particular field and appear to visualize the materials represented, but in many cases the result has no greater significance in terms of intellectual progress than the impact of light rays picturing a particular landscape on the retina of an ox. There must be some conscious relation of the elements represented to each other, or in the sense of research and knowledge nothing happens.

In the case of phenomena such as those of the Grand Canyon observers may look into the depths of the great gulf, with its rugged and spectacular walls, and of fifty persons receiving the same picture on the retina only one or two may have a sense of understanding of what it means. Another person may come who fits the various elements together and who brings out of his experience the beauties of color and form, the grandeur of height and of mass, and with this the sublimity of power and of changes in the past which have produced these effects, and at the same time have recorded the lapse of ages, constituting one of the most important elements of the picture. As yet we have made only too little progress in the attempt to find the way to interpret the facts of science so as to make them intelligible, not merely to the public, but to investigators in other fields of research as well. In reality this constitutes one of the major problems involved in consideration of the future of science and of knowledge.

Granted that we become expert in the simple and clear interpretation of data in the various fields of research, it becomes possible then to bring the pictures of these aspects of research together, and to form opinions concerning their relation to one another; thus bringing about relation of materials which may furnish the foundations for generalizations; the generalizations in their turn contributing toward interpretation of details in other fields.

So there is reason to believe that in any scheme by which we attempt to secure the fullest values through research, and from the organization of knowledge, we will be dependent to a considerable extent upon our ability to interpret the details in such form that they may be fitted into the general setting, and thus help to advance those gen-

eralizations which may become fundamental principles of science.

As the program develops, it becomes increasingly clear that one function of the Carnegie Institution lies in making possible such relation of its various types of specialized research to one another as will bring largest values for each research, and will also facilitate building upward in the broader scheme of knowledge. This process will depend in some measure upon acceptance of the idea that all elements of nature, and of knowledge, have interrelationships. We now realize that no science can exist alone; no branch of knowledge can exist alone; all must be related to other knowledge if they are to attain their largest value.

Illustration of ways in which ideas expressed above are found to work out in practical operations of the Institution is furnished by types of activities presented in our conferences, as well as by programs of annual meetings, for which such excellent facilities are available in Elihu Root Hall with the exhibit rooms and conference rooms grouped around it.

It is the custom of the Division of Animal Biology to aid in advancing development of special investigations, as also of broad interpretations of phenomena covering more than one group, by arranging conferences for all of the departments and special investigation groups comprised in the Division. These gatherings occur at the laboratories of the departments, and are so arranged that meetings pass in rotation through the major groups. Illustration of the mode of procedure, and of the influence of such gatherings, is furnished by the conference of the Division held at Cold Spring Harbor on October 28th of

this year. Meetings of similar type, but with somewhat different organization, are held also from time to time by other Divisions and groups of the Institution.

The Cold Spring Harbor conference of October 28th was attended by representatives of the departments or groups of Genetics, Eugenics Record Office, Embryology, Nutrition, and Tortugas Laboratory, together with Research Associates, and with them collaborating investigators from a considerable number of institutions. Members of the staff at Cold Spring Harbor participated in the proceedings, and a group of staff members was present also from the other departments and groups. The conference included a preliminary period without special program, in which the investigators could discuss problems of mutual interest without the restrictions of a detailed plan. A formal program was initiated at 11:00 o'clock by presentation of seven papers on special subjects. Four of these were prepared by members of the staffs of departments, two by Research Associates, and one by a collaborating investigator. The papers were all carefully prepared, and eventually all will be published, either as separate articles or included in more extended studies or reports. The list is as follows:

- M. DEMEREC—Nature of X-ray Induced Hereditary Changes in *Drosophila*.
- C. B. BRIDGES—Constitution of Germ Plasm in Relation to Heredity.
- E. C. MACDOWELL—Leukemia Studies with Heat and with Trypan Blue.
- O. RIDDLE—Regulation by the Anterior Pituitary.
- H. H. LAUGHLIN—Blood Kinships within Eight Degenerate Families.
- E. W. SINNOTT—The Effect of Polyploidy on Fruit Shape in Cucurbits.
- H. C. SHERMAN—Influence of Nutrition upon Body Composition.

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Each paper was limited sharply to a time within fifteen minutes, after which there was opportunity for discussion. The program was brought to a close in time for luncheon, at which the investigators gathered in the dormitory of the Department of Genetics.

Following luncheon, visitors were invited to study and to discuss exhibits by the investigators representing various divisions of work being conducted at Cold Spring Harbor. The extraordinarily well planned materials were described briefly by the persons in charge, and there was free discussion of the problems illustrated and their ultimate significance. Of the twenty exhibits available for study by visitors, the following illustrate the types of research:

- A. D. BERGNER—Types of chromosomal deficiencies due to colchicine treatment.
- S. SATINA—Identification of specific chromosomes in pollen grains.
- A. G. AVERY—a. 15-year breeding records showing effect of different extra chromosomes upon size of seed, percentage of germination, viability, and spontaneous non-disjunction.
b. Method of securing homozygous races through doubling chromosomes of haploids by colchicine treatment.
- H. E. WARMKE—a. Sterile hybrids made fertile by chromosome doubling.
b. Somatic criteria of polyploids in different species.
- E. W. SINNOTT and MISS HOSKINS: Effect of polyploidy upon fruit shape in squashes.
- C. B. BRIDGES—Vestigial deficiency.
- M. DEMEREC and MISS HOOVER—Hairy wing duplication.
- B. P. KAUFMANN—An induced reverse repeat.
- E. C. MACDOWELL—Details of leukemia studies with heat and with trypan blue.
- R. W. BATES—Factors affecting the response to prolactin.
 - a. Sex hormone treatment.
 - b. Sex difference.

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DR. SCHOOLEY—Relations of pituitary to size of body and viscera.

DR. SCHOOLEY and MR. LAHR—Hormonal basis of maternal behavior and broodiness.

a. Maternal behavior in rats.

b. Coincidence of prolactin-release (colchicine technique) with beginning broodiness in pigeons.

c. Broodiness in doves with progesterone treatment.

DR. SCHOOLEY and DR. MILLER—Cytology of pituitary and adrenal.

a. Formation of new cells in anterior pituitary.

b. Cytological changes of adrenal cortex in experimental animals.

MRS. SMITH—Relations of the pituitary to heat production in pigeons.

a. Effects of intermedin and "adrenotropin" on basal metabolism.

b. Influence of prolonged fasting on the basal metabolism of normal and hypophysectomized animals.

O. RIDDLE—On relation of pituitary hormones to carbohydrate and calcium metabolism.

C. B. DAVENPORT—Changes in head-form during post-natal development.

BARBARA S. BURKS—Autosomal linkage in man.

H. H. LAUGHLIN—Blood kinship of a selected-near-kin to the subject-individual, and the degree of development of the subject-trait in such selected-near-kin, as two computable factors in the prediction of development of the subject-trait in the subject-individual.

In the course of examination of the exhibits there was much discussion of relation between the investigations, as also concerning relation between problems presented by the researches at Cold Spring Harbor and those of other departments of the Division. Altogether it was evident that there was not only sharpening of the incisiveness in research with reference to individual projects, but that there was a marked broadening of view regarding the whole problem of animal biology, with the possibility that entirely new and important problems might arise out of the discussion.

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In discussion regarding future problems of the Institution, in 1930 attention of the Trustees of the Institution turned toward the need for increase of facilities in the

**Elihu Root
Hall**

Administration Building to be used in connection with service to the public through interpretation of research results by lectures, conferences, exhibitions, and publication. It was proposed then that additional space be provided for conference rooms, for offices to be used by visitors engaged in research and by members of the staff temporarily in residence in Washington for research purposes, for additional auditorium space for general lectures, and for facilities such as would permit exhibition of research results without requisitioning office quarters of the administration staff. In 1931, on recommendation of Senator Root, an initial appropriation of \$30,000 was made toward a building fund to carry out these plans. In that year distinct advance was made in the whole program of public relations, and there was record of further progress toward a building scheme in the purchase for this purpose of a tract of ground consisting of four lots immediately to the east of the Administration Building.

The proposed building program was discussed through several years following acquisition of the first additions to the building area needed, but the generally unfavorable financial situation made it necessary to move slowly in accumulation of funds for this purpose. In this period Senator Root frequently expressed the opinion that the project was of the first order of importance to the Institution and was a type of activity which Mr. Carnegie would have wished to see advanced. In 1936 the Executive Committee took action to realize the building project

with the purposes as defined. It voted from the Special Emergency Reserve Fund a sum of such limits as would be adequate for the project and made funds available for initiation of the program as early as possible. As Senator Root was not present at the meeting at which this action was taken, two members of the Committee were delegated to call upon him at once and announce effective realization of the plan in which he had taken such deep interest.

Building operations began in September 1937, under the guidance of Mr. William Adams Delano as architect and have proceeded to completion and occupation in ample time for activities connected with the annual meeting in 1938. Fitting well to the original Administration Building erected in 1908, and yet possessing a degree of individuality, the new quarters are dignified and artistically pleasing throughout. The carefully planned offices meet a need which had been recognized only in part by the staff by reason of its effort to make the best of some rather difficult situations in the past. The space designed for use in connection with exhibition arrangements is not only much superior to what has been available heretofore, but it permits these activities without dispossessing important staff officers of the Institution of their quarters at such times as the annual meeting, when it is desirable that they have favorable opportunity for consultation with Trustees, visiting directors, and staff members.

Readjustment of space use in the older part of the building makes possible utilization of rooms for the Division of Historical Research, and other space is prepared for distinguished investigators of our staff and from other institutions who visit us each year. Quarters for the pub-

lications staff are adequate for the first time, and greater effectiveness in operation is at once apparent.

To the auditorium in the new quarters the Trustees, on motion of Governor W. Cameron Forbes, have given the name Elihu Root Hall, and upon this part of the structure the greatest possible care has been bestowed, in order that it may serve to express appreciation of Senator Root's service to the Institution through the thirty-five years of his trusteeship, and his continuing contribution toward improvement and clearer statement of the ideals and objectives of the Institution. Of modest and yet adequate size, the auditorium furnishes opportunity for better discussion of results in research than has heretofore been possible. A Committee of the Trustees gave special attention to decoration of the room. The results attained under direction of Mr. William Adams Delano, the architect, and Mr. J. Monroe Hewlett, the artist, constitute a real contribution to the application of art to use in cooperation with science.

Completion of the new quarters available for advance of conferences and for interpretation of research opens the way to new and better opportunities, not only for education, but, in an even wider field, for organization and advancement of knowledge.

The types of activity that center in Elihu Root Hall, with the exhibition and conference rooms grouped around it, have given in recent years an important opportunity in the Institution for conference and discussion on both special and general subjects. The assembled exhibits always represent some of the most important researches from each group, shown under the most favorable conditions for interpretation. It has become a habit for the entire group

of exhibitors to go through the whole exhibition together, with each person explaining his materials to the others. The mutual education accomplished has led to many discoveries of relationships in research, and to development of not a few new joint investigation projects. Just as the division conference has served to interpret and to educate a considerable group to advantage of the individual investigator, so the general Institution exhibition has performed a similar service for the whole Carnegie Institution staff, including officers, Trustees, and distinguished guests.

The possibilities of Elihu Root Hall, together with the equipment of the new quarters, for performing large service to the public, such as seems a natural responsibility for an agency like the Carnegie Institution, must be considered of great significance. In developing the policy of presenting interpretations of research in the form of press releases, it was assumed that the principal objectives would concern the considerable group of widely-reading persons not especially interested in conduct of research. But, to the surprise of those examining the situation, it appeared that the first important evidences of approval came not so often from the lay reader, or from the applying engineer, as from investigators in other fields. It seemed, then, that the interpretation program was serving a purpose of importance in relating to each other researches of the intensive type, for study of which one would at the outset expect only a limited audience. It appeared that in these operations contribution was being made to interrelation of projects and their results, which is to be desired in a world characterized by unity of nature, and that these are logical steps toward organiza-

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tion of knowledge so clearly essential in any major plan for aid in advancement of learning.

With the evident multiplicity of important investigations under way within the program of the Institution it has never been possible in the special statement made by the President, to touch more than a small part of those having immediate significance. It is, moreover, to be noted that the Year Book, which becomes available to the Trustees on the day of the annual meeting, contains report on the entire program, and that volume as a whole constitutes the real report of the President. The increasing simplification of departmental reports by the directors has contributed in an important way to the possibilities of reviewing the year's activities. It is also desirable to note that the bibliography, comprising pages 406 to 432 in the Year Book, covers the results in publication of the past year, and furnishes an important picture of the program as a whole.

Special Phases of Research Advance

Without making distinctions concerning ultimate values, there are among contributions completed or brought to climax in the last year a number of investigations which may well receive special mention.

MOUNT WILSON OBSERVATORY

In the field of astronomical research no record of the year would be complete without mention of the finished and published report on Magnetic Observations of Sun Spots, 1917-1924, by Dr. George E. Hale and collaborators, representing the results of many years' work by him and his associates, and appearing now after many years' preparation. The publication of this great work, brought

to conclusion by Dr. Seth B. Nicholson, constitutes one of the notable achievements in astronomical research.

Part I describes the solar telescopes of Mount Wilson Observatory and gives the history of their development. The observations and theories which led to the discovery of magnetic fields in sunspots are discussed; and the methods and equipment used in measuring their field strengths and polarities are described in detail. A scheme for classifying sunspots magnetically is given and all the spot-groups observed from 1917 to 1924, inclusive, are classified for each day. A law describing the magnetic properties of sunspots is deduced from the observations.

Part II contains the daily magnetic observations of each sunspot observed from 1917 to 1924. The observations are recorded on drawings of the solar disk reproduced on a scale of seven inches to the sun's diameter.

Dr. Hale's great contribution to study of sunspot phenomena, described in detail in the foregoing publication, came as a direct consequence of his interest in the improvement of instrumental facilities and his remarkable skill in the designing of new apparatus. Dr. Adams in an article in *Astrophysical Journal*, May, 1938, comments upon this characteristic of Dr. Hale, saying:

"The invention of the spectroheliograph and the spectrohelioscope and the adaptation of the tower telescope and the vertical spectrograph for solar investigation are excellent examples of this quality of Hale's mind. In part it was probably due to his engineering training, but much more to his appreciation of the enormous importance of the value of improved instruments to astronomical progress, and to his creative ability and love of fine workmanship. He took immense pleasure in seeing a new

instrument assume form; and, as he often said, 'Had I not been an astronomer, I should have liked to have been an instrument-maker.' "

Continuing comment upon Dr. Hale's recognition that advance of research on astrophysical problems could be gained only through improvement of the tools used by the investigators and through the development of new and more powerful instruments Dr. Adams writes:

"The establishment of the Mount Wilson Observatory gave Hale, for the first time, the opportunity of building instruments on a large scale to fit the problems to be investigated rather than of finding the problems to be undertaken with an existing instrument. This is the point of view of the physicist and was a principle maintained by Hale throughout his life. The Snow telescope was designed for certain specific purposes, primarily to make possible the use of larger spectrographs and the violet region of the spectrum; the 60-foot tower telescope, to improve seeing conditions on the sun's image and afford convenience of operation and temperature control for very long spectrographs; and the 150-foot tower telescope, to afford a very large solar image for the study of sunspots and details on the sun's surface.

"The same attitude was taken with reference to the stellar instruments, the 60-inch and 100-inch telescopes being designed for use at three foci, so that the magnification and the auxiliary instruments could be adjusted to the problem in mind. Hale was always greatly interested in the coudé form of the reflecting telescope, appreciating from experience the value of large-scale stellar spectra and the immense advantages of fixed instruments operated under laboratory conditions."

In tracing the steps leading up to Dr. Hale's great discovery, steps described at length in the publication above referred to, Dr. Adams says in part:

"Hale started with the simple and altogether natural working hypothesis that the differences of intensity between the same lines in spots and on the disk of the sun are due to the lower temperature of spots. Accordingly, an investigation was begun in the laboratory to study the effects of temperature on the spectra of various elements. The arc spectrum of iron was photographed, first with a rotating arc, then in an arc through which currents of widely varying amount could be passed, and finally in the outer flame and in the central core of an arc.

"The results were decisive in showing a great difference in behavior among the lines, some being relatively strong in the spectrum of the low-current arc and the cooler outer flame, while others were strong only in the hot central core and in the high-current arc. Comparison with the spectrum of sunspots at once showed that the 'low-temperature' lines of the laboratory were just those which were greatly strengthened in spots while the 'high-temperature' lines were but little affected. The final evidence that the effect was due to temperature was provided by a simple electric furnace, which gave results precisely similar to those found with the arc.

"This investigation was of great importance not only because its results explained many of the most important phenomena of sunspots but also because it had far-reaching consequences. The classification of lines according to temperature behavior made at this time, and improved and greatly extended by King with the electric furnace, laid the foundation for much of the analysis of spectra in

later years. The discovery of the weakening of the enhanced lines in sunspot spectra and the ensuing laboratory investigations led to the suggestion that low density might be favorable to the production of enhanced lines, a conclusion so fundamental in the theory of ionization. Finally, these results had extremely wide applications to stellar spectra, aiding in determinations of temperature and density, and through successive stages leading to the spectral differentiation of giant and dwarf stars and the discovery of the spectroscopic method of determining parallaxes.

“Observations with the spectroheliograph were continued regularly by Hale and Ellerman during these years at Mount Wilson, and some experimental work with this instrument led to results which culminated in Hale’s most brilliant discovery. Sufficient progress had been made in sensitizing photographic plates to red light by means of dyes, especially by R. J. Wallace, to permit the use of the spectroheliograph with the α line of hydrogen.

“Photographs with this line at once showed a variety of detail, both in dark and bright flocculi, which had not been seen previously in observations with the $H\delta$ line. Most important of all, Hale’s skilful examination at once detected in the curved form of the flocculi about sunspots evidence of vortical motion. Further observations fully confirmed this opinion, in one case a very long dark flocculus, which showed gradual curvature as it approached a double spot, finally forking and being drawn into the two centers of the vortex. That he foresaw at once the consequences of this discovery is shown by two quotations from his article on solar vortices:

“ ‘In view of the fact that the distribution of the hydro-

gen flocculi frequently resembles that of iron filings in a magnetic field, it is interesting to recall the exact correspondence between the analytical relations developed in the theory of vortices and in the theory of electromagnetism.

“ ‘Double lines, which look like reversals, have recently been photographed in spot spectra with the 30-foot spectrograph of the tower telescope, confirming the visual observations of Young and Mitchell. It should be determined whether the components of these double lines are circularly polarized in opposite directions, or, if not, whether other less obvious indications of a magnetic field are present. I shall attempt the necessary observations as soon as a suitable spot appears on the sun.’

“On June 25, 1908, Hale obtained a series of photographs with the 30-foot spectrograph, using a Fresnel rhomb and Nicol prism. These gave unmistakable evidence of the Zeeman effect and of the presence of a magnetic field in sunspots.

“Following this remarkable discovery, Hale devoted considerable time to measurements of the strength of field in spots, comparisons with laboratory results, studies of plane polarization across the lines of force, and experimental work on vortex models. Since the resolution of the components of many of the spot lines was beyond the power of the 30-foot spectrograph, he decided to postpone further extensive investigations until the completion of the 150-foot tower telescope and the 75-foot spectrograph, which were under construction in 1909 and 1910. The decreasing sunspot activity, however, and the scarcity of spots led him at this time to undertake an investigation particularly well suited for sunspot minimum but ex-

traordinarily difficult and exacting because of the smallness of the quantities involved. This was the problem of the existence of a general magnetic field of the sun as shown by the Zeeman effect. Here there could be no question of the separation of lines into components, but, as computation showed, only of minute displacements, when the Nicol prism was rotated, of three or four thousandths of a millimeter even on the great scale of the spectra with the 75-foot spectrograph. A large amount of observational material was required, and the measurements were undertaken by van Maanen and other members of the Observatory staff.

“Positive results were obtained which were discussed by Hale in an extensive article written in March, 1913; but the problem was rendered even more difficult by the apparent failure of certain lines to show the expected effect. The investigation was continued by Hale up to the end of his life, and he developed several ingenious and effective devices for measuring the minute quantities involved. New series of photographs were obtained near the sunspot minima of 1922 and 1932; and the spectra were measured, but with somewhat inconsistent results. It is very difficult to draw a definite conclusion regarding the outcome of this long research undertaken with such great skill and patience. The presumption for the existence of the general magnetic field seems to be strong, but the definite proof may have to await new methods or improved instruments.”

Reference in the foregoing statement to the part played by instrument improvement in the progress of astronomical research suggests mention of the fact that after many years of constant use the 60-foot tower telescope is now in

process of reconstruction. When the remodeling is completed, this telescope, the first instrument of the type ever built, will include features of convenience suggested by past experience and others made possible by modern developments in science and industry.

The mountings of the coelostat and second flat mirrors are being redesigned, a new drive installed, and many features added to provide for the automatic registration of the sun's image throughout the day. The mounting of the 10-inch photographic telescope is also being remodeled and a photovisual objective has been designed to aid in the photography of object-prism spectra in the yellow and red region.

Respecting the investigational work of the staff for the year Dr. Adams' report shows that gratifying progress has been made in all of the projects constituting the Observatory program.

The year has been especially propitious for conduct of the various researches relating to solar phenomena because of unusual disturbances in the sun that have been taking place. The number of sunspot groups observed during the year, for example, is the greatest since the Observatory was established. Moreover, the largest groups of the year, groups which crossed the sun's central meridian on July 28 and October 4, 1937, respectively, were among the six largest groups that have ever been observed at the Observatory.

Spectrograms of several large stable sunspots were obtained for use in the photometry of the spot spectrum. Four selected regions were photographed on successive days, when the observing conditions were excellent, as the spot moved from east to the west limb. Much informa-

tion concerning the structure of sunspots may be obtained from spot spectrograms taken in this way.

The faintness of rare-earth lines in the solar spectrum is well known, and most of those hitherto identified belong to the ionized atom. With the aid of laboratory data on europium, which has been obtained, more than 20 of the neutral lines of this element have been identified with faint solar lines. This increases the known singly ionized europium lines in the sun from 5 to 27.

An eruptive prominence, observed on March 20, rose in two and one-half hours to a record height, falling just short of a million miles or about one and one-eighth times the sun's diameter. Analysis of the motions gave three successive velocities of 42, 85, and 125 miles per second.

Dr. Edison Pettit, who has been studying these eruptive prominences for many years, spent three of the summer months at the McMath-Hulbert Observatory collaborating with Mr. R. R. McMath in study of prominences. This is the only observatory equipped to take motion-pictures of the sun. Previous experience has however shown that in such study the motion-picture equipment gives results of definite value. During his stay seven eruptive prominences were observed and motion-pictures taken of them, making a total of nine for the year, the largest number ever observed, the average for 50 years being one per year.

The prominence observed on September 17, 1937, rose to a height of 625,000 miles, with observed velocities, approximately, of 18, 36, 115, 340, and 455 miles per second. Observations of this prominence reduce the time interval required for a velocity-change from the previous estimate of 5 to 10 minutes to less than 45 seconds.

Dr. Pettit reports that continuous observation of an active prominence over a considerable period occasionally reveals faint streamers, unconnected with the prominence, entering the center of attraction from high up in the coronal region. About a dozen of these "coronal" prominences have been observed and five have been measured in detail.

Over an active sunspot group small, nearly round masses of chromospheric matter occasionally shoot out and, unlike the surges, do not return. These "ejections" are usually very faint, many being at the limit of vision on the films. Aside from surges and ejections, all motions in sunspot prominences are downward to the spot.

Ordinarily, streamer formations above a sunspot are preceded by the appearance of a bright, nearly round cloud, which feeds the streamers extending from one side of the cloud to the spot area. Sometimes the cloud elongates and feeds streamers from both ends, the prominence matter moving down both branches of the loop. Such loop formations are frequently seen over sunspot groups. Particular attention is being directed to these streamer formations in the attempt to determine their significance.

Recent discovery of the tenth and eleventh satellites of Jupiter by Dr. Seth B. Nicholson, and further observation on the ninth satellite constitute an important advance in the study of planets and the bodies accompanying them.

In the first order of interest among natural phenomena has been also the continued investigation of novæ and supernovæ, among the most mysterious and interesting and ultimately probably some of the most important objects of astronomical research. Refined methods of

spectroscopic study in this field have given materials of much interest, and researches of this type are held to represent a field of exceptional promise for the future.

Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, has completed the series of visual measurements of the percentage amount of plane polarization in light diffusely reflected by lunar and terrestrial materials and is now preparing the report on the results. To study the polarization of moonlight and of sunlight diffusely reflected by terrestrial substances, a new high-gain, alternating-current amplifier has been constructed in the laboratory of the Department of Terrestrial Magnetism from designs by Mr. Ellis Johnson of that Department. The instrument is used with a rotating Nicol prism (10 cycles per second) and furnishes an independent check on visual measurements. Preliminary tests indicate that it operates satisfactorily and has adequate sensitivity for the measurement of the intensity of the polarized component of the incoming beam; it also measures the total intensity of the incoming beam, but with smaller precision.

During July Dr. Wright photographed the lunar surface at brief intervals throughout the full lunation taking 500 pictures in so doing. The photographs were made at the Newtonian focus of the 100-inch reflector with the aid of a zero corrector, which functions extremely well over the spectral range $\lambda 5000$ – $\lambda 6000$, and will form the basis for a topographic reconnaissance map of the central portion of the moon.

In study of galactic nebulae Dr. Walter Baade has continued his program of direct photography through red filters, giving special attention to the region of the galactic

center. The investigation is of exceptional importance because it has partially penetrated the heavy obscuration that hides the nucleus of our system. A survey in duplicate (red and blue) of the region galactic longitudes 300° to 350° , latitudes $+8^{\circ}$ to -8° , made with the 18-inch Schmidt reflector on Mount Palomar, fully confirms the strong selective absorption reported a year ago. The greater space penetration of the red films, relative to the blue, introduces marked differences in the pattern of obscuring clouds. Further, various faint extended nebulosities, absent or inconspicuous in the blue survey, are well recorded in the red, presumably by strong $H\alpha$ emission. For instance, NGC 6357, of which only one or two small wisps appear in the blue, is an outstanding object on the red films, rivaling in size the Orion Nebula and Messier 8. Among a number of new clusters found during the survey, subsequent checks with the large reflectors disclosed half a dozen very heavily obscured globular clusters.

Dr. Baade states that one difficulty encountered in this work is due to the variable, and sometimes heavy, sky fog appearing on the red films after only moderate exposures. Since the fog on a given night is a function of zenith distance, its source must be atmospheric—probably the red auroral lines. It seems possible, he thinks, that the occasional difficulties encountered during the past half-year may have been due largely to the high frequency of sunspots, now near maximum. To test this point a spectroscopic investigation is now under way.

In study of the extragalactic nebulae the major development during the past year has been the cooperative study of two supernovae in a manner more detailed and compre-

hensive than has hitherto been possible. Supernovæ represent the sudden release of energy on a scale which far transcends that of any other known phenomenon (one of the two recent supernovæ reached a maximum luminosity of the order of 10^9 suns). For the first time, sufficient information has been assembled to investigate, rather than to speculate upon, the behavior of matter and radiation under the extreme conditions represented by the explosions.

In the general field of extragalactic research, emphasis has been shifted from the study of the observable region as a sample of the universe, to the detailed investigation of nebulae as stellar systems. The problems of nebular structure and evolution have replaced, for the time being, the problem of cosmology.

During the year an extensive observing program was finished by Dr. Edwin P. Hubble which was undertaken for the purpose of obtaining good photographs with the large reflectors of the 800 nebulae in the Shapley-Ames catalogue, north of declination minus 30° and equal to or brighter than the limit of completeness at photographic magnitude 12.9. The task of enlarging the Mount Wilson collection of photographs to meet these specifications has required the cooperation of several observers over a period of years. In the course of this and other more special programs, photographs of many fainter nebulae have also been assembled until the collection now includes about 2000 NGC objects and nearly 1000 given in the IC.

Since the material is complete for the brighter nebulae (over three-quarters of the sky) and probably representative for the fainter objects, attention has now been diverted from the compilation to the analysis of the data.

The investigations include detailed, quantitative studies of the sequence of classification, of the relative frequencies of various types, and of the small-scale distribution of nebulae.

Dr. Adams reports that the new auditorium and exhibit hall on Mount Wilson, which were completed last year, are serving admirably the purpose for which they were intended. The exhibit of astronomical photographs, shown as transparencies, is open to the public on Friday evenings and for an hour each afternoon. The dome of the 100-inch telescope is also opened each afternoon and the mechanism and operation of the instrument are explained to visitors. Friday evenings an illustrated lecture is given in the auditorium preceding the demonstration at the 60-inch telescope, to which visitors are admitted on these evenings. In the summer months, when the crowds are large, visitors who cannot gain admission to the lecture hall go at once to the 60-inch telescope. During the year, 11,191 visitors were admitted to the 60-inch telescope for the Friday evening demonstration—1000 more than for the preceding year, in spite of the fact that for three months Mount Wilson was inaccessible to the public because of storm damage to the Angeles Crest Highway.

THE GEOPHYSICAL LABORATORY

In reporting upon the work of the Geophysical Laboratory for the year just closed, Dr. L. H. Adams, the Director, makes clear the relation of this program to the conceptions set forth to explain the origin of the earth's physical structure. According to this view, two opposing forces, operating through vast periods, account for the earth's structure as we now know it. One is expressed

in differentiation, by which is meant the change of matter from a simple to a complex state, with a corresponding build-up of the reserves of energy. The other is the process of assimilation, meaning the incorporation of one rock mass into another, and representing, generally, a change towards greater uniformity or simplicity, resulting in a corresponding degradation of form and energy and loss of the dynamic quality possessed by the more complex substances.

The changes in the physical world, according to this view, may be thought of as consequences of these processes. Moreover, the tendency in nature is for aggregations of matter, if left to themselves, to become uniform throughout, and, ultimately, to become completely homogeneous in composition and texture and wholly static in respect to energy.

Dr. Adams comments on this idea as follows:

“The significant fact is that the primary tendency for all aggregations of matter is a degradation of form, of energy, or of composition. Mountain masses are reduced to peneplanes, thermal energy becomes unavailable for useful work, and mixtures become homogeneous in composition and texture. But although the tendency is ever toward the state in which individuality is destroyed, there are intermediate stages in which the natural and usual course of events reverses itself; we have alternate cycles of the twin effects that, depending on the factors to be emphasized, may be designated as mixing and unmixing, planation and upheaval, diffusion and segregation, destruction and creation, decay and growth, or assimilation and differentiation—different names for the one set of fundamental opposing tendencies.

“Viewed in a broad way, the problems of geophysics are largely those of differentiation. Whether all or a part of the Earth was once uniform in composition, it is now decidedly heterogeneous, and differentiation is responsible for those aspects of its geologic history that are the most interesting and also the most puzzling. It is easy to understand how materials can mix to form a solution, but it is difficult to acquire adequate knowledge concerning the mechanism by which they can unmix. A land surface by well-known processes is reduced to a level plane, and subsequently by forces that are not yet well understood is uplifted to great heights. There is a general tendency to reduce the state of all things to a dead level, and the consequences of this tendency are simple. The reverse effect of building up structures and differences in composition is complex and often appears to defy explanation. In many instances we can predict the course of processes by which structures are torn down but not the manner in which they may be built up again.

“That part of the Earth’s crust amenable to direct or indirect observation offers a fascinating series of problems, which in common with all problems present a challenge to the inquiring mind. In accepting the challenge we resort to laboratory experimentation and in effect presume to imitate Nature on a small scale. At the Geophysical Laboratory our attack has proceeded in three principal directions: (1) By crystallization or by other means, we induce the separation of mixtures into their constituents (solid, liquid, and gaseous) and define the conditions necessary for the appearance of the individual phases; (2) we search for mechanical processes that will sort, transport, and arrange the products; and (3) we

study the structure of solids and liquids, utilizing the most powerful devices of modern physics, in order to predict the behavior of mixtures subjected to varying environment."

During the year the investigators on the Laboratory staff have made significant progress along each of these major lines. Important light has been thrown on the properties of lavas, on the phenomenon of volcanism, and on the mechanism of flowage in masses of molten silicates through investigation of the volatile constituents of natural rocks, which has included comparison with gases arising from volcanoes. Studies of the incrustations from volcanoes and fumaroles have shown the presence of a surprising number of the less familiar elements, suggesting that the deposition of these elements by volatile transport is an important factor in the formation of iron ores.

Closely related to the work of the Geophysical Laboratory and, in effect, a part of its program, are the studies of volcanic phenomena of Montserrat, one of the islands of the Lesser Antilles, conducted by Mr. F. A. Perret, a Research Associate of the Institution. The results of the study will soon be issued by the Office of Publications of the Institution as a companion volume to publications by the same investigator on Vesuvius and Mount Pelée.

Observations of the volcanic and seismic activity on this island have been supplemented by studies on a new and similar phase of activity at Dominica, another of the Lesser Antilles, located between Montserrat and Martinique. The volcanoes of the Lesser Antilles, with their accessible peaks, continuing activity, and alternating periods of volcanic and seismic play, have afforded a valuable opportunity for investigation of such phenomena.

The program of the Laboratory provides for projection of this study of volcanic action to Guatemala where preliminary examination during 1932 and 1935 disclosed a profitable field for investigation. Funds for the purpose are available and plans for field studies have been formulated. Through cooperative effort and applying modern physical methods, it is hoped that something of the underground structure in the vicinity of an active volcano will be learned.

The work of the Laboratory during the year also included investigation of several mixtures containing water as an active ingredient. Among them were: boron oxide and water, which reveals some of the conditions in which crystallizable substances make their appearance; calcium sulphate and water, study of which has solved some difficult matters relating to the formation of gypsum deposits; and sodium hydroxide and water, a study marking the first step in a program of investigations of silicate systems at moderate temperatures and pressures. This last series of investigations was made possible through financial aid given by the Carnegie Corporation of New York and has, as its specific objective, information about the formation of the coarse crystal growths of granitic rocks known as pegmatites and about the alteration of minerals due to the action of heated waters.

In the Institution's Year Book for 1935-36, No. 35, announcement was made of the development by Dr. Charles S. Piggot, of the Geophysical Laboratory staff, of an apparatus for obtaining core-samples of the ocean bottom at great depths. A number of such samples are now available and are being studied at the Laboratory

and elsewhere along with samples of the ocean floor collected by dredging during voyages of the *Carnegie*.

TERRESTRIAL MAGNETISM

In the field of physical sciences one of the most notable advances in the Institution's program of the past year is marked by completion of the improved atomic physics equipment constructed by the Department of Terrestrial Magnetism for use in study of magnetism in its relation to the atom. The new equipment comprises a constant-potential generator and vacuum-tube designed to reach potentials in excess of five million volts under precise control. The care with which the apparatus has been designed and finally realized as a completed instrument should guarantee the greatly bettered facilities for experimentation which this new tool is intended to give. The construction of this long-planned equipment was begun in May 1937. The equipment will greatly extend the possible scope of the Department's investigations of the nature of magnetism and the basic structure of matter.

A second accomplished project is that of the installation of automatic multifrequency equipments at the Huancayo (Peru) and Watheroo (Australia) Magnetic Observatories for study of the magnetic conditions of the ionosphere. This equipment, developed at the Department, has the following characteristics: capability of recording accurately without interference from existing radio services; relatively uniform vertical radiation throughout the frequency range; automatic interlocking of transmitting and receiving tuning; mechanical simplicity and uniform limits of precision and resolution.

With this equipment the stations at Huancayo and

Watheroo, operating continuously in conjunction with similar equipment at the station of the National Bureau of Standards, Meadows, Maryland, should provide a much more nearly complete survey of the region of the upper atmosphere than has hitherto been possible. Tests of the apparatus at the Department's experimental station at Kensington, Maryland, promise settlement of many vexing questions as to the magnetic conditions prevailing in the zone of the upper atmosphere.

One of the most interesting recent developments of research in the Institution has arisen through cooperation of the Geophysical Laboratory and the Department of Terrestrial Magnetism. The long cores obtained recently from the Atlantic sea bottom by Dr. Charles S. Piggot, of the Geophysical Laboratory, are seen to include a great number of layers apparently representing a record of many thousands of years. Particles included in these layers are found to show magnetic orientation, and the orientation may not be the same in different parts of the core. Similarly in sedimentary deposits of geological formations there is evidence that the rocks may retain the magnetization imparted to them by the earth's magnetic field at the time of their deposition.

If the conditions and variations of magnetization are finally demonstrated to represent conditions which they seem to reflect, a method will have been developed for following magnetic changes through long periods at given localities, and this makes possible a picture of earth history heretofore not attainable.

This development introduces into the study of magnetic phenomena a distinctively new element, one which Dr. Fleming has aptly called palæomagnetism. The method,

in process of refinement, gives promise of becoming a powerful new tool. By this method, it is hoped, much will be learned concerning the magnetic history of the earth during past geological ages.

The year has been one of unusual interest in the opportunities it has afforded for study of solar and terrestrial relationships, and of the relations between terrestrial magnetism and other phenomena, such as cosmic radiation. Since the last sunspot minimum of 1933, there has been a steep increase in solar activity, as expressed by sunspot numbers, reaching a value for 1937 considerably exceeding any annual mean since the high sunspot maximum of 1870. Intensity of magnetic disturbance followed this increase and the year 1937 proved to be the most active year for over 60 years, although individual storms of outstanding intensity did not occur until 1938.

In commenting upon the positive relationship of cosmic radiation with magnetic and other phenomena, Dr. Fleming writes:

“Worldwide decreases of 3 to 5 per cent in daily means of cosmic-ray intensity are found to be associated with changes in the Earth’s magnetic field during two major magnetic storms; other magnetic storms of equal intensity occur with no appreciable cosmic-ray effects. Thus it appears that the entire current-system for the storm-time field of both types of storm cannot be located at the same distance above the Earth. A significant correlation between changes in daily means of cosmic-ray intensity for two stations separated 50° in latitude probably results from the mechanism responsible for the magnetic-storm effect. Statistical analyses of the cosmic-ray records obtained at Cheltenham and at Huancayo proved inadequate

to establish a sidereal diurnal variation in cosmic-ray intensity.

“Analysis of all available data from Cheltenham, Teoloyucan, Christchurch, and Huancayo shows that the major changes in the 10-day means of cosmic radiation are all worldwide. The correlation between the worldwide changes at different stations was found high enough to provide important information regarding their variation with latitude and altitude. It seems impossible to explain the annual waves found at these stations in terms of a solar magnetic moment.”

DIVISION OF PLANT BIOLOGY

Dr. H. A. Spoehr, Chairman of the Division of Plant Biology, reports the bringing to completion of an extensive series of investigations, begun in 1922, to determine the effect of climate in the modification of plants, and the manner in which the latter are differentiated to meet the complex demands of various environments. These investigations, known as transplant or varied-environment experiments, have been carried out at a number of stations located so as to represent a range in altitude extending from sea level to the crest of the Sierra Nevada.

Although analysis of the extensive accumulation of data has not been completed, nevertheless it has gone far enough to indicate certain results, chief of which are:

1. Demonstration of the delicacy of balance between the internal or gene-controlled factors and the external environment.

2. Comprehension of the orderly complexity of species composition in relation to plant distribution.

3. Evaluation of the capacity of plants to adjust themselves to different environments.

During the year two investigations dealing with the chemistry of the photosynthetic apparatus of plants have been brought to publication. In referring to these studies Dr. Spoehr writes:

“The first of these concerns the leaf xanthophylls, a group of yellow pigments contained in all chloroplasts. Because of the fact that these substances possess a very complicated chemical structure and because the various members of the group differ only very slightly in structure and in their chemical properties, their isolation and purification have been associated with many difficulties. The isolation of these extraordinarily sensitive compounds was made possible largely through the development of special methods of chromatographic adsorption. By this means and through the accurate determination of the absorption spectra reliable methods have been evolved for the characterization of this important group of naturally occurring substances.

“The other investigation referred to concerns the mechanism by which the plant leaf absorbs the carbon dioxide of the atmosphere. This is the first step in the series of chemical reactions comprising photosynthesis. The more exact determination of the chemical system which is involved in this first step has served to establish another link in the series of chemical reactions comprising the photosynthetic process.

“Photosynthesis in plants is essentially an energy-storing chemical reaction. This energy is obtained from the light which is absorbed by the pigments in the leaves of the plant, and is used in reducing carbon dioxide to

a carbohydrate. The amount of energy which is required by the plant to carry forward this chemical reaction is of fundamental importance in establishing the chemical mechanism which is involved in the process. During the past year a reinvestigation of the quantum efficiency of photosynthesis has been begun by Drs. Robert Emerson and Charlton M. Lewis, with a view to making certain essential amplifications of previous determinations with improved apparatus, and with special consideration of the physiological characteristics of the plant organisms used."

In respect to the quantum efficiency of photosynthesis Drs. Emerson and Lewis show that in the reduction of carbon dioxide to carbohydrate a minimum of 112,000 calories for each unit, known as a mole, of carbon dioxide is required. In reporting their work on this subject these investigators say:

"In green plant photosynthesis, the energy necessary for this process is obtained through the absorption of visible light by chlorophyll. Photosynthesis proceeds normally in red light, where the energy obtainable from a number of light quanta equal to the number of molecules in a gram-mole (one mole-quantum) is only about 40,000 calories. Several light quanta must therefore be absorbed in order to provide the minimum amount of energy required to reduce one molecule of carbon dioxide.

"According to the present concepts of physics, absorbed light quanta cannot act additively, but only individually, so we may suppose that each absorbed quantum effective in photosynthesis brings about a single elementary step in the process of carbon dioxide reduction. If three quanta of red light were available for each molecule of

carbon dioxide, there would be $3 \times 40,000$ or 120,000 calories per mole, an amount greater by 8000 calories than the theoretical minimum of 112,000. But each individual step must require some activation energy, for which a margin of only 8000 calories would hardly be sufficient. Therefore it is generally believed that nothing less than four quanta can be regarded as providing enough energy for the reduction of one molecule of carbon dioxide to carbohydrate."

In further summary of the work of his staff for the year Dr. Spoehr states:

"The recent publication of the results of thirty years' observation of changes in vegetation on the fenced lands of the Desert Laboratory has attracted the interest of both foreign and American workers who are dealing with the problems of restoration and maintenance of grazing ranges. Shorter periods of observations of the reproduction and growth of large desert perennials have emphasized the slowness of growth of individual plants and the long periods required to bring about change in the communities which they form.

"The close of active field work on the Sonoran Desert project, which has been one of the principal activities of the Desert Laboratory for the past five years, has been followed by study of notes and collections preparatory to publication. The work of the past year has been almost as fruitful as the years of exploration, since it has given time for the study of living and herbarium material and the collection of data on climate vegetation, and the distribution of some of the most highly specialized desert plants. The objective of these investigations has been the determination of the origin of desert plants and their

differentiation under the impact of the severe environmental conditions of the arid regions.”

DIVISION OF ANIMAL BIOLOGY

Question of the geographical separation of the groups comprising the personnel of the Division of Animal Biology and ways of lessening the disadvantages arising therefrom are discussed by Dr. George L. Streeter, Chairman of the Division. The problem which he touches upon in connection with his own Division is likewise a problem incident to the entire Institution organization for, in general, groups of Institution workers are placed where their work has naturally developed or where it can be conducted to best advantage.

Thus, the Nutrition Laboratory was located at Boston; the Division of Historical Research with sections working at Washington, in Yucatan, in Guatemala, and in Cambridge; the Department of Embryology at Baltimore; the Geophysical Laboratory and the Department of Terrestrial Magnetism at Washington, with observatories of the latter in Peru and Australia; the Mount Wilson Observatory at Pasadena; the Division of Plant Biology at Stanford University, with sections at Tucson, at Santa Barbara, at Carmel, at Berkeley, and at Pikes Peak; and the Marine Biological Laboratory at Tortugas.

Were nothing done to overcome the drift, this physical separation of the units of the organization would lead quickly to a sense of detachment and heterogeneity with consequent loss of Institutional efficiency. Much thought has been given to the question of how best to overcome this centrifugal tendency. As a partial answer has come the

Institution's program of conferences, exhibitions, lectures, and interpretative statements.

Dr. Streeter's discussion of the problem as it relates to his own Division, the units of which are located at widely scattered points, is timely. Respecting this matter he says:

"The activities of the component groups under the Division of Animal Biology are reported in the following pages and it will be seen that in general they include related phases of physiology, anatomy, embryology, and heredity of animals. The question repeatedly arises as to whether it would be desirable to bring these researches all under one roof, so to speak, or at least in one locality. Much might be gained by a closer assembly, but it would also involve some sacrifices.

"Even were such a concentration feasible, careful consideration should be given to all the factors concerned. The present arrangement has been one of natural evolution. The various projects have sprung up where it was thought they could be best conducted; some in large scientific centers, others in isolated locations where environments of a special character were demanded by the nature of the project.

"As far as possible, the disadvantage of the dispersion of the research personnel has been counteracted by frequent conferences and exchange of facilities between the individuals of the different groups. As a consequence, it is more and more being found that a community of interest and cooperative endeavor are of mutual advantage and an added source of strength. Inasmuch as the selection and grouping of the researches have been of an evolutionary or empirical nature it is to be expected that

their goals and planning will be subject to change and adjustment from time to time.

“Projects are dropped as they reach a reasonable completion and attention is turned in other directions. Trial and error are dominant features in the organization of the groups and subgroups just as they are in their researches and as they are in nature. The investigator is on the fringe of the unknown where in his uncertain advances he must be alert to advantageous alterations in course. He must have a plan but his plan must not commit him to a program that cannot be terminated when it becomes barren.”

Since October 1936 the Eugenics Record Office of the Institution, under direction of Dr. H. H. Laughlin, Assistant Director of the Department of Genetics, has been collaborating with the State of Connecticut in a survey of the human resources of that commonwealth. The Governor of the State appointed a commission with Frederic C. Walcott as chairman.

The Governor duly instructed this commission to make a thorough survey of the human resources, good and bad, of the State of Connecticut, and particularly to investigate the source, the apparently increasing supply, and the racial, moral, and economic costs of those human inadequates who finally either directly or indirectly become economic charges or moral debits of the state, the county, or the town.

The commission, in turn, appointed Dr. Laughlin director of the survey. An office and exhibit room were duly opened in the State Office Building at Hartford, and an office and field staff began work.

Early in 1938 the collection of the data was completed

and analysis of the returns and preparation of the survey's report begun, of which the complete material has now been laid before the commission. This general report covers such researches as the following:

1. Analysis of the laws of Connecticut in direct reference to the human resources of the State.

2. Assemblage of data on the inadequate and handicapped residents of each of the 169 towns of Connecticut.

3. Special consideration of the problem of the feeble-minded in Connecticut, comprising a study of nearly 12,000 persons in respect to important qualities or factors.

4. A study of the 661 inmates of the Connecticut State Prison for Men at Wethersfield.

5. The direct cost to the people of the State for the care, training, and treatment of the defective, dependent, delinquent, and handicapped classes.

In respect to this last study the findings show the astonishing facts that in 1937 the people of Connecticut, through their State government, were expending more per capita for the handicapped classes than the State government was expending for all purposes twenty years ago; also, that at the present rate every inhabitant of Connecticut is expending, through the State government, five and one-third times as many dollars per year on these groups as the average inhabitant was spending for the same purpose twenty years ago.

In the field of embryology Dr. Streeter states that the year has brought notable success, in that the effort to obtain younger mammalian ova that are assuredly dated has extended the known field another twenty-four hours. In 1934 he reported having obtained a 10-day macaque embryo, whereby observational knowledge of the mechan-

ism of development was extended into the twenty-four hour period preceding any then known primate ovum.

The year following he was able to report two 9-day specimens, one just before implantation and one in process of attachment to the uterine wall. This year the finding of an 8-day primate ovum has given the investigators material from which much can be learned about the first and most fundamental chapter in development of the body tissues of the mammalian organism. In describing this 8-day ovum of the macaque monkey and telling of its importance Dr. Streeter writes:

“An outstanding feature of it is the fact that at the embryonic pole there are still a few cells that are approximately double the size of the others. It is clear to see that they have not divided so many times. These relatively inactive cells appear to be the ones that are destined to form the embryo proper. They are large, few in number, not oriented in position, and show no tendency to unite into a common structure, all of which are characteristic of primitive blastomeres.

“In contrast to these primordial cells, the other cells are numerous, small, and are rapidly differentiating into special structures which will serve to attach the ovum to the uterus and eventually provide the contained embryo with its nourishment and other physiological requirements. In the point of sequence the stage is set before the embryo makes its appearance.

“In this blastocyst Dr. Heuser finds that he can see clearly that the materials of the ovum have, already on the eighth day, been segregated into the embryonic and extra-embryonic, or auxiliary, parts of the ovum. Thus the eighth day may be said to mark the completion of the

first and hence the most fundamental chapter in the development of the ovum."

In the parallel effort to push further back toward the beginnings of the human organism Dr. Streeter reports opportunity of studying a 15-day old presomite specimen at the Anatomical Laboratory of the University of Chicago. This specimen he says is certainly normal, is in a good state of preservation, and is destined to take its place as a standard of orientation in the procession of stages through which the human embryo passes in its development. A slightly younger specimen, known as the Yale Embryo, probably between 13 and 14 days old, has also been subjected to careful study as has a third human embryo, younger still than either of the others.

A review by Dr. W. H. Lewis of his studies on the cultivation and cytology of cancer cells, an investigation that has extended over a period of some years, confirms his previously expressed opinion that cancer cells are permanently altered cells. That is to say, they constitute new types that are derived from normal and usually healthy cells, which have been permanently altered by environmental influences or various other agencies. After the normal cells have undergone the initial alteration into malignant cells, he says, the special environmental influences or agents which produced them are not necessary for the maintenance of their peculiarities.

Dr. Lewis finds that in tissue cultures the malignant cells are visibly different from normal ones and from each other. They retain their peculiar characteristics from one generation to another when serially transplanted from animal to animal and for months or even years. From six of the tumors malignant cells were cultivated "in glass"

for two to over four years. In that way pure colonies of the malignant cells were obtained which retained both their cultural characteristics and their malignancy. When inoculated into animals typical tumors resulted. From these, in turn, pure colonies of characteristic malignant cells were secured and these also produced typical tumors.

Last year Dr. A. F. Blakeslee, Director of the Department of Genetics, reported the discovery that treatment of the seeds of *Datura* (Jimson weed) with the alkaloid colchicine would bring about changes in structure of the seedlings which were interpreted as due to doubling the number of those minute elements known as chromosomes. It was pointed out that if the interpretation were correct and the methods could be used with other forms, a tool of considerable value would be available both to the practical plant breeder and to the plant geneticist interested in problems of evolution. Dr. Blakeslee reports that the present year's work has shown that induction of chromosome doubling by chemical treatment is of wide application among flowering plants and enables the investigator of certain problems to work with a measure of precision not hitherto possible.

Soaking seeds in solutions of colchicine of different concentrations for different species is the most convenient method of treatment. Seeds of *Portulaca* respond to the concentration of 0.0002 per cent for two days by producing seedlings with swollen stems. Seed treatment with 0.4 and 0.8 per cent solutions for 4 to 8 days has been found well adapted to *Datura* and induces an abundant production of $4n$ branches.

The effect of the drug is first noted in delaying germination and development. When the treatment is severe the

stems of the seedlings are strongly swollen and many fail to develop beyond the cotyledon stage. The leaves of affected plants are characteristically roughened owing to the fact that they contain a mixture of $2n$ and $4n$ cells. From these "mixochimeras" there ultimately may grow out branches with smooth leaves which either are normal $2n$ or contain twice the normal number of chromosomes and are therefore $4n$. The $4n$ flowers may be recognized by the larger size of their pollen grains or by the more tedious method of actually counting the chromosomes in young buds which have been fixed and stained by the acetocarmine method.

In addition to the seeds, vegetative parts of the plant may be treated by a variety of methods. The most successful method consists in spraying growing points with solutions or better with emulsions containing colchicine. On the other hand it was found that injecting solutions and allowing solutions to be soaked up through the cut parts of the stem were not successful.

One of the early problems in the use of colchicine was the extent to which this drug would be effective in doubling the chromosome number of other forms than *Datura*. A number of species were selected for testing because of their adaptability to experimental cultivation or because of their relation to special problems.

The species successfully treated represent a considerable number of genera and families, enough to indicate that the method is of wide application. In addition, a number of forms which showed the vegetative peculiarities characteristic of tissue with doubled chromosome number following colchicine treatment were discarded for various reasons before the special treatment required

to force out $4n$ branches had been developed. This was notably true of the grass family, but other investigators who have specialized on this family have recently been successful in securing $4n$ races of grasses through treatment with colchicine. The fungi seem highly resistant to the toxic action of colchicine.

Interesting attempts were made to double the chromosome number in animals through employment of the colchicine method. Trout eggs were used in the hope that through treatment the fusion nucleus could be induced to double its chromosomes before the first division.

In all the experiments, however, difficulty was encountered in getting the drug to penetrate the membranes and so, in consequence, the efforts were unsuccessful. It is thought possible that eggs which develop outside the body are better protected against unfavorable environmental influences than those which develop within the body. In consequence the latter might be more promising material in which to attempt chromosome doubling despite the technical difficulties involved in handling the eggs of such species.

Dr. Oscar Riddle and his associates in study of the endocrine system report that it has now become clear that the pituitary gland is largely responsible for the regulation, adjustment, and coordination of this system and for certain other activities of body and mind besides. It would now seem possible, they assert, to conclude that in higher animals and man the brain and the pituitary gland are the two prime sources from which the activities of an individual are derived.

The investigations reported here, like those of past years, present parts of an effort to learn those endocrine

agencies and mechanisms which condition or control functions such as growth (development), reproduction, and regulation in the bodies of higher animals and man. Much of the experience of the year points to the unpredictability of relationships among hormones; and perhaps the most notable thing observed is the extent to which one hormone may either increase (synergize) or decrease the specific action of another. These studies of Dr. Riddle and his associates have been greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

On November 1, 1937, Dr. Francis G. Benedict, Director of the Institution's Nutrition Laboratory since its establishment in 1908, retired. Since Dr. Benedict's retirement the work of the Laboratory has gone forward under supervision of Dr. Thorne M. Carpenter, the Acting Director.

Dr. Carpenter reports that the early part of the year was occupied, for the most part, in an intensive effort to complete the preparation for publication of monographs and journal articles by Dr. Francis G. Benedict before his retirement as Director. This was most successfully accomplished, and the several publications have gone through the press.

The experimental work for the year has continued largely in the same fields of research as have already been in progress. In spite of considerable observation on the biological variations in basal metabolism, there are still gaps in the data and excellent leads for future study, particularly of those animal species in which there are large variations in size and configuration.

Dr. Carpenter states further that there is at present a

renewed interest in bodily heat regulation, as evidenced by the number of recent publications concerned with the distribution of heat elimination, the skin and the body temperature. The present increasing use of methods of air conditioning, particularly air cooling (some of which are far from satisfactory either from the physiological standpoint or from the standpoint of comfort), indicates the need of more knowledge of human heat regulation in response to rapid and unusual changes in environmental conditions. The past experience of the Nutrition Laboratory in the studies of skin and body temperatures and its experimental equipment, particularly the emission calorimeter for humans, provide conditions for a comparative study of heat production and heat elimination which would be of value in understanding the physiological processes of the body when there is a necessity for rapid adaptation to changes in environmental conditions.

DIVISION OF HISTORICAL RESEARCH

The staff of Historical Research has devoted the year largely to organizing accumulated data and to the writing of reports, it being the policy of the Division not to undertake new researches until record has been made of earlier activities. This has served to focus special attention upon problems of publication. Respecting this matter the chairman of the division, Dr. A. V. Kidder, makes the following observations:

“In general, first class factual literature in the social sciences and the humanities is pitifully scanty. In these, as in the natural sciences, the collection and the setting forth of data must precede synthesis and the drawing of conclusions. And because of the bewilderingly faceted

life of man and the infinitely wide range of man's doings throughout the ages, in every conceivable type of historical setting, and in all possible sorts of physical environments, the human record must, for the present at least, be largely descriptive.

"Expression by formula is not feasible, nor can there often be used the condensed forms appropriate for exposition of the regularly repeating phenomena of biology. Publication, therefore, even in the case of the relatively small group of studies with which the Division is occupied, is inevitably voluminous; archæological papers must carry a great amount of illustration.

"Costs, accordingly, are bound to be heavy; but, on the other hand, it is only fair to point out that acquisition of most anthropological and historical materials is relatively inexpensive, there being little or no call for physical equipment, for laboratories or instruments. However, neither need for much publication nor cheapness of fact finding justifies waste. Also, from the point of view of utility, it is essential that results be thoroughly digested and succinctly stated.

"Because of the vast increase in scientific writing of all sorts, as well as because of the rapidly mounting costs of printing, it is certain that present methods for dissemination of knowledge will have to be rather drastically overhauled, those of the disciplines concerning man perhaps most severely of all. How this may be brought about, in the case of its own product, is being given anxious consideration by the Division. Those of its reports which are now well along in preparation will be submitted in forms sanctioned by previous practice. But it is probable that current studies of the situation will result in recommen-

dations looking towards much simplified presentations and considerable reduction in manufacturing costs."

In pursuance of the policy of making suitable record, from time to time, of investigations finished or well advanced, Dr. Kidder reports completion of two outstanding studies made by members of the section of Aboriginal American History. One of these is a compendious monograph of five quarto volumes representing the fruits of the twenty years of study which Dr. Sylvanus G. Morley has devoted to the hieroglyphic inscriptions found in the ruined Maya cities of the Department of Peten, Guatemala. The other is by Mr. Earl H. Morris, who has spent an equally long time in studying the very important Basket Maker and Pueblo sites of northern New Mexico and adjacent regions. These two monographs, the one now in press, and the other being prepared for the press, will rank as fundamentally significant contributions to the literature of their respective fields.

After eleven seasons spent in excavation work at Uaxactun, in the Department of Peten, Guatemala, presumably the oldest known of the First Empire cities of the Maya, activities were brought to an end in 1937. The findings of the first years as reported by Dr. and Mrs. Oliver G. Ricketson have recently been published by the Institution. Work at this site during the last six years was largely devoted to study of the so-called "Palace," a multi-chambered structure which grew by accretion through a long period, and where thorough study by Mr. A. L. Smith has yielded very valuable data upon architectural development and the succession of pottery types. Mr. Smith and his associates in study of the "Palace" are engaged in preparing the final report upon the general archæology

of the sites and upon results of the study that is being given the enormous collections of ceramic material that were made at Uaxactun.

Dr. Kidder also reports termination of work on the mounds and tombs of Kaminal-juyu, near Guatemala City, a project to which he has given his personal attention. The collections which he obtained at the site, particularly those of pottery, throw much light upon the chronological relations between the cultures of the Guatemala highlands, of the Maya First Empire in Peten, and those of central Mexico. Through collapse of the roofs of the tombs, the mortuary pottery was found to have been badly crushed and broken, in consequence of which the task of repairing the more than two hundred vessels, many of great beauty, and of types hitherto unknown, has been one of great difficulty. The work of repair is going forward steadily, each completed piece is photographed, artists are reproducing the particularly fine pieces in black and white or in water color, and ultimately all the pieces will be placed in the National Museum at Guatemala for permanent exhibition.

As to the activities of the staff group working in post-Columbian American history Dr. Leo F. Stock spent the summer in England in gathering material for the fifth and last volume of the series, *Proceedings and debates of the British Parliament respecting North America*. This series when completed will contain all the contemporary records that can be found, in print or in manuscript, of what was done and said in the parliaments of England, Scotland, and Ireland concerning North America, from the first mention of that continent to the conclusion of peace and acknowledgment of American Independence in 1783.

In January of 1938 the Institution brought out the third and last volume of the series, *Historical documents relating to New Mexico, Nueva Viscaya, and approaches thereto, to 1773*. These volumes contain texts and translations of a large number of documents, hitherto unknown to historical scholars, which were found by the late Dr. Bandelier and Mrs. Bandelier in the Archivo General de Indias in Seville and elsewhere. The documents present a wide variety of material, illustrating all portions of the history of the Rio Grande region from the first exploration of it by the Spaniards.

Although the monumental series of eight volumes entitled *Letters of members of the Continental Congress* was completed by Dr. E. C. Burnett in 1936, since that time he has been at work upon an interpretative volume which is based primarily upon the published series. The series contains practically all the contemporaneous evidence that could be found bearing upon the discussions arising in the Congress. Much of it consists of letters which members wrote from day to day, from the seat of the sessions, to the governors or other authorities of their states, or to relatives and friends. Arranged in chronological order, these letters and extracts by various members, from different states, cast a flood of light upon the transactions of the Congress throughout fifteen momentous years.

In the effort to bridge the gap between the present and the pre-Columbian past through study of the documentary history of the Peninsula, there has been included in the Maya program the accounts of the conquerors and early ecclesiastics regarding the aboriginal condition of the Maya.

Dr. Kidder comments on certain aspects of the History of Yucatan project as follows:

“At the present time it has seemed desirable to inquire more closely into what the white man found when he arrived in the various parts of the Maya area; the state of affairs at the time of this contact, as distinguished from subsequent developments influenced by European culture, on one hand, and previous conditions no longer existing but disclosed by archæological investigation, on the other.

“There are some indications that more or less similar conditions may well have existed for at least three centuries prior to the Conquest in the highlands of Guatemala and perhaps considerably longer in regions between that area and the state of Yucatan. In Yucatan, however, there was a great political and social revolution about the middle of the fifteenth century. Its more conspicuous effects were the breaking up of a centralized government and the abandonment of the stone-vaulted buildings, which were replaced by more or less perishable structures with thatched roofs. In the Old World such a decline in architecture has been either more gradual or the result of invasion and immigration by less cultured peoples, which was not the case in Yucatan at this time. Much of the previous state of affairs, which reminds us in some respects of the conditions in the highlands of Guatemala at the time of the Conquest, was still a matter of general knowledge when the Spaniards conquered Yucatan, so it may be possible to trace the causes and effects of this famous crisis in aboriginal American history.”

In work of the Section on History of Science, during the year, Dr. George Sarton has made excellent progress in preparation of the third volume of his monumental

series, *The Introduction to the History of Science*. In this work Dr. Sarton has had the help of Dr. Alexander Pogo who, while assisting Dr. Sarton, has continued his astronomical studies bearing on the problem of the correlation of Maya and Christian chronologies.

Study of the history of Greek thought has been diligently prosecuted by Dr. W. A. Heidel, who throughout the year has been chiefly occupied with the history of Greek mathematics down to 400 B. C., or rather with the attempts made by various modern scholars to describe the development from data that are exceedingly meager.

ST. AUGUSTINE AND MONTEREY RESEARCH PROJECTS

Cooperative studies in history of two early American cities arising out of Spanish culture have been carried on at St. Augustine, Florida, and Monterey, California. While these activities have arisen independently, in certain respects they are intimately related, since both concern study of Spanish influence upon the United States and express in some measure a connection with activities of the Institution in contiguous areas of Latin America.

The program of work at Monterey had been carried on by investigators in California for a number of years, much having been accomplished in preservation of historic sites and in study of valuable materials. The Institution has cooperated so far as possible in preserving the Monterey Custom House, one of the most important sites, and has continued its interest by supporting activities of Mr. Emerson Knight and Dr. Aubrey Neasham in study of the plan of the city with reference to history of outstanding monuments and materials. Extraordinarily fine coopera-

tion of the citizens of Monterey, and their activity in protection of things of historical value, give reason to believe that there is developing at that place one of the most important opportunities for study of the Spanish influence upon the United States. A general plan of the city, now being developed through cooperation of the principal agencies related to the government of Monterey, has produced a picture of what may be done with the city, and marks definite progress in development of the area.

Study on the St. Augustine research project, concerning which a statement appeared in the annual report of 1937, has advanced rapidly in the past year, with emphasis upon those features which give evidence of furnishing the outlines of a picture covering the story of this, the oldest city of the United States, from the date of its founding up to the present time. Determination to center investigation upon a report covering development of the defense system of St. Augustine, and its relation to the frontier of Florida, has made it possible to concentrate information from many sources in an extremely interesting report by Verne E. Chatelain on "The Florida Frontier and Its Defenses, 1565-1785." This work has been completed for publication, and will contribute in a very definite way to development of a program for interpretation of this very striking story involving contacts with Spain, France, and England, on the southern border of what is now the United States.

The investigations in this problem of the defenses and the Florida frontier from 1565 mark an important advance in study of the area, and they are intimately connected also with other investigations which have to do with the broader story of the region reaching into the

interpretation of economic and governmental problems. In other directions the researches extend into the field of general archæology of southeastern United States, and it is hoped that ultimately the complete story of human occupation of this region may be made available.

Cooperation of the citizens of St. Augustine in these studies has included not only aid in furtherance of the historical and general scientific researches, but has involved as well the preparation of a general plan for development of this region. This project looks toward a zoning program in which the things of major value historically may retain their scientific and historical significance, and at the same time fit into a general æsthetic scheme making for the most acceptable living conditions in the city and its immediate environment.

EARLY STAGES OF HUMAN HISTORY

In the earlier reaches of history as relating to man, there has been continued progress during the past year on many problems of unusual interest. The studies of Dr. H. deTerra on early man in Asia were extended from India to southeastern Asia and then to Java. Cooperation of Dr. P. Teilhard du Chardin in conduct of these investigations gave opportunity to bring into this program of study the combined data and experience from researches in India and China and to apply all available information to the program planned for the southeastern region.

In his visit to Java Dr. deTerra had the cooperation of Dr. G. H. R. von Koenigswald, who has contributed so largely to knowledge of the *Pithecanthropus* problem. Review of the *Pithecanthropus* region of Java by these investigators has given a more extensive and a clearer

picture of the geology and palæontology of the region than has hitherto been available.

In extension of his researches of last year in Java Dr. von Koenigswald was successful in obtaining additional *Pithecanthropus* material, giving important skull characters. The recent find throws still further light on the structure, stage of evolution, and relationships of this most interesting creature.

In America study of early man was extended by Dr. L. S. Cressman, of the University of Oregon, who has continued to discover new cave sites in eastern Oregon containing remains of early man, who seems to have lived there near the time of beginning occupation of that region. In several caverns volcanic ash or pumice occurs above deposits containing human relics. In the Paisley Cave this ash seems, according to Dr. Howel Williams, to have come from eruption of Mount Mazama, which occupied the site of Crater Lake to the south.

Contribution of new information from Clear Lake, California, by Mr. M. R. Harrington, furnishes a record of unusual interest and promise, with human relics apparently of great age. Excavations by Mr. Malcolm Rogers, of the San Diego Museum, have given a story of deposits of much significance, and with the record of a culture that promises important advance in knowledge of the earlier stages in America.

Dr. E. Antevs has continued his critical studies on climate in relation to early man. His researches have furnished some of the most important evidence available on relation of the history of early man to climatic changes, and to evolution of life that was associated with ancient man in America.

HISTORY EXPRESSED THROUGH GEOLOGY

Extension of history into the earliest available records has carried investigators cooperating with the Institution into sections of the Grand Canyon where some of the beginnings of our earth story are recorded. Mr. Edwin D. McKee has shown relation in structure between ancient formations of the Grand Canyon and recent deposits of the Colorado Delta, and in connection with his studies has published an important work on the rocks of the upper Canyon wall.

Dr. N. E. A. Hinds has continued his extraordinarily interesting work on the series of Grand Canyon formations just below the level where a satisfactory record of life begins.

The expedition carried through the Grand Canyon by Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, late in 1937, obtained new and important data in the oldest part of the known record, where the original structure of the rocks has been altered by processes which in the hands of time bring great changes. The results of this study throw new light on one of the most interesting chapters of earth history.

OBITUARIES

The death of Dr. William Wallace Campbell on June fourteenth, 1938, removed from the group of Trustees of Carnegie Institution one who had shown himself exceptionally competent and effective both as a member of the administrative board and as adviser and counselor in practically the whole range of scientific and human problems which the Institution encounters. Dr. Campbell was especially

**William Wallace
Campbell**

CARNEGIE INSTITUTION OF WASHINGTON

fitted for service on the Board of Trustees of the Institution by his long and distinguished career as an investigator in astronomy, his administration of Lick Observatory, his service as President of the University of California, his wide experience in administration of great scientific organizations, such as, the National Academy of Sciences and the American Association for the Advancement of Science, and above all by his broad and deep interest in the types of problems which the Institution might be expected to meet.

After his election to membership on the Board of Trustees in 1929 Dr. Campbell was present at all meetings excepting those for which attendance was impossible by reason of illness. On every occasion when it was possible to give service, he was ready and eager to aid in study of critical questions confronting us. The measure of his interest and understanding of the Institution seemed almost to rank with that of the persons who were intimately acquainted with the ideals and purposes of the Founder. There may be no doubt concerning the great influence of his advice and judgment in advancement of the Institution program along the best lines open during the period in which he served as a member of the Board of Trustees.

Through the period of his connection with the Carnegie Institution, beginning in 1905, and extending to the date of his death on February twenty-second Dr. George Ellery Hale devoted to the problems of astronomy which he developed at Mount Wilson a type of interest and attention rarely found in any investigator. His exceptional talent and wisdom applied through Mount

Wilson Observatory made a contribution which marks an epoch in astronomical research. In addition to the record made by specific researches, and in his fine administration of Mount Wilson Observatory, Dr. Hale performed a service of great importance to the Institution and to science through the influence of his example in advancing standards of thought and work. To an unusual degree Dr. Hale illustrated the significance of leadership in an organization. It is interesting to note also that the great research project built around the specific program of Mount Wilson Observatory extended an influence in all directions, ranging from the effect upon developing institutions devoted to science and education as at California Institute, to education regarding the practical significance of fundamental physics as applied in great industries depending often for their ultimate development upon advances in basic physics.

Among the many and varied types of institutions devoted to astronomical research, Mount Wilson Observatory and its associated activities constitute an outstanding result of the creative interest and activity of Dr. Hale. Initiated originally for the purpose of natural and proper concentration of attention upon the nearest star, namely, the sun, the investigations extended themselves in every direction through the universe, carrying the data obtained from the sun to interpretation of other stars, and on into the outer fields of nebulae and problems of the universe. Back again to the sun, these lines of thought turned to interpret more fully the solar problem, in some measure in terms of what was learned through study of other stars. So the work of Dr. Hale contributed powerfully both to stimulation of the most intensive type of research on par-

ticular problems, and to development of those broader principles which underlie our understanding of the nature and structure of the universe.

Development of astronomy by adaptation of methods devised and carried out by Dr. Hale will continue through the ages. Though the means utilized for furtherance of research may change quickly to types apparently little related to those now in use, there can be no dimming of the influence that Dr. Hale's work at Mount Wilson will continue to exert upon astronomical and physical research of future epochs.

BUDGET OF 1939

Corresponding to the situation generally in organizations largely dependent upon income from securities, preparation of a budget program from 1939 has presented difficult problems, at least to the extent of estimates affected by shrinkage of income below that of 1938. Careful handling of investments by the Finance Committee and the Investment Office has, however, developed a situation which is relatively less difficult than seems to appear in many agencies with comparable problems.

Fortunately, the generally unsettled conditions in the field of investment and finance made clear before the beginning of the past year the desirability of planning for such adjustments as would make possible in 1939 a continuation of the Institution's program without serious dislocations. The carrying over through 1938 of unallotted funds gave a considerable sum to be added to normal income. Care in handling of expenditures during the past year permitted retaining of a Contingent Fund of such size that an important contribution could be placed in

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the Income Account for 1939, and still leave for the remainder of this year a Contingent Fund adequate to protect the present budget.

REPORTS ON INVESTIGATIONS

DIVISION OF ANIMAL BIOLOGY

GEORGE L. STREETER, CHAIRMAN

The activities of the component groups under the Division of Animal Biology are reported in the following pages and it will be seen that in general they include related phases of physiology, anatomy, embryology, and heredity of animals. The question repeatedly arises as to whether it would be desirable to bring these researches all under one roof, so to speak, or at least in one locality. Much might be gained by a closer assembly, but it would also involve some sacrifices. Even were such a concentration feasible, careful consideration should be given to all the factors concerned. The present arrangement has been one of natural evolution. The various projects have sprung up where it was thought they could be best conducted; some in large scientific centers, others in isolated locations where environments of a special character were demanded by the nature of the project.

As far as possible, the disadvantage of the dispersion of the research personnel has been counteracted by frequent conferences and exchange of facilities between the individuals of the different groups. As a consequence, it is more and more being found that a community of interest and cooperative endeavor are of mutual advantage and an added source of strength. Inasmuch as the selection and grouping of the researches have been of an evolutionary or empirical nature it is to be expected that their goals and planning will be subject to change and adjustment from time to time. Projects are dropped as they reach a reasonable completion and attention is turned in other directions. Trial and error are dominant features in the organization of the groups and subgroups just as they are in their researches and as they are in nature. The investigator is on the fringe of the unknown where in his uncertain advances he must be alert to advantageous alterations in course. He must have a plan but his plan must not commit him to a program that cannot be terminated when it becomes barren.

One of the projects that were brought to a conclusion during the past year is the survey of the human resources of Connecticut. This was undertaken as a cooperative study by a commission appointed by the governor of the state of Connecticut and the staff of our Eugenics Record Office. The survey was of importance to the state because of the alarming and increasing expenditures necessary for the care and treatment of its socially inadequate classes. It was of interest to the staff of the Eugenics Record Office because such a survey fell directly in the field of eugenic and population studies with which they were especially equipped to deal. Now after two years of concentrated effort the factual data, covering the biological and eugenical aspects of the problem, have been collected, classified, and analyzed and placed at the disposal of the Commission. It is realized that the biological point of view, though a very important one, is but one aspect of this population problem and it happens to be the one to which our facilities are limited.

DEPARTMENT OF EMBRYOLOGY ¹

GEORGE L. STREETER, DIRECTOR

EARLY STAGES OF THE PRIMATE EMBRYO

THE EIGHT-DAY PRIMATE EGG

In Year Book No. 33 a report was given of the obtaining of a 10-day macaque embryo and it was pointed out that our vision of the mechanism of development was thereby extended into the 24-hour period preceding any hitherto known primate ovum. The year following we were able to report two 9-day specimens, one just before implantation and one just in the process of attaching. With these two eggs the known territory was extended another 24 hours earlier. During the past year we have obtained an 8-day ovum and again a still earlier 24 hours has been mastered. This carries us back to where, in its histological structure, the primate ovum is close kin to other mammalian forms, and to where they have in common the developmental pattern of a blastocyst. It is of the greatest importance that we have acquaintance with this expression of their common unity in functional requirements and the common way they have of meeting them. In going back to origins, once this unity is arrived at, any of the earlier developmental phenomena are in large part common to all mammals and we can in those early periods study them in any order, genus, or species that suits our convenience.

The 8-day ovum of the macaque consists of a blastocyst having a diameter of 0.175 mm., still enclosed by a disintegrating zona pellucida. This unique specimen was reported upon by Dr. C. H. Heuser before the American Association of Anatomists. An outstanding feature of it is the fact that at the embryonic pole there are still a few cells that are approximately double the size of the others. It is clear to see that they have not divided so many times. These relatively inactive cells appear to be the ones that are destined to form the embryo proper. They are large, few in number, not oriented in position, and show no tendency to unite into a common structure, all of which are characteristic of primitive blastomeres. In contrast to these primordial cells, the other cells are numerous, small, and are rapidly differentiating into special structures which will serve to attach the ovum to the uterus and eventually provide the contained embryo with its nourishment and other physiological requirements. In the point of sequence the stage is set before the embryo makes its appearance. In this blastocyst Dr. Heuser finds that he can see clearly that the materials of the ovum have, already on the eighth day, been segregated into the embryonic and extra-embryonic, or auxiliary, parts of the ovum. Thus the eighth day may be said to mark the completion of the first and hence the most fundamental chapter in the development of the ovum.

IMPLANTATION

The second chapter in the history of the ovum is its attachment and implantation in the endometrium of the uterus. But this is a long and complicated process overlapping the subsequent stages and so is not exactly a

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chapter. Implantation must begin, however, and establish its initial principles before growth and development of the ovum can ensue. Some phases of this process have been described in previous reports. During the past year a study of placentation in the macaque has been brought to a conclusion by the author in cooperation with Dr. G. B. Wislocki and published in its completed form. The study is based on a series of stages representing an almost day by day record from the ninth day when the egg first fastens, through the early and formerly least-known phases of placental development, up to the 35th day, by which time the mature features of the placenta are attained. In fact this constitutes the only relatively complete record in existence of the development of this fetal structure in any primate. The earlier stages are quite unknown in the gibbon and the anthropoid apes and in man our knowledge is fragmentary concerning all events preceding the 14th day.

From the biological standpoint the phenomenon of implantation is of peculiar interest. Here we have the ovum as a minute living organism attaching itself to the surface epithelium of the uterus and, after inducing both stimulative and degenerative changes in it, we see the ovum ingest this altered epithelium, with a corresponding increase in its own mass. The whole picture of this act of parasitism can be followed in its finer cytological details and one can determine the microscopic characteristics of the surrender of one living tissue to another. During the first two weeks this ingestion of maternal cells and intercellular plasma provides the sole source of growth material for the embryo and for a long time it overlaps the materno-fetal vascular exchange which, to a large extent, gradually replaces it.

The placental development is found to pass through three general periods or stages. The first of these is the prelacunar stage, in which trophoblast cells of the ovum erode and ingest the maternal epithelium at the implantation site and thus come in direct contact with the uterine stroma. While this is happening the maternal epithelium of the surrounding area proliferates, thereby building more pabulum for the trophoblast cells to fatten on. Within 24 hours a thick trophoblastic plate is formed at the embryonic pole of the ovum, sealing in the gap created by the disappearance of the maternal epithelium.

A second stage follows during which the trophoblastic plate, in continuing to thicken, develops lacunæ into which the maternal capillaries empty and promptly fill with plasma and red cells. These spaces greatly increase the absorptive area and there is a corresponding increase in the amount of trophoblast. The very rapid growth of trophoblast that takes place in three days is shown in the figure on page 6, where B to D represent the prelacunar stage and E to H represent the second or lacunar stage. The third or villous stage follows directly after the above stages. In the available material one can plainly follow the formation of the chorionic villi and the differentiation of cytotrophoblastic columns, the centers of which become transformed into reticular connective tissue and capillary-forming cells and thus compose the cores of the villi. The details of this transformation were previously described by Dr. Hertig as referred to in a previous report (Year Book

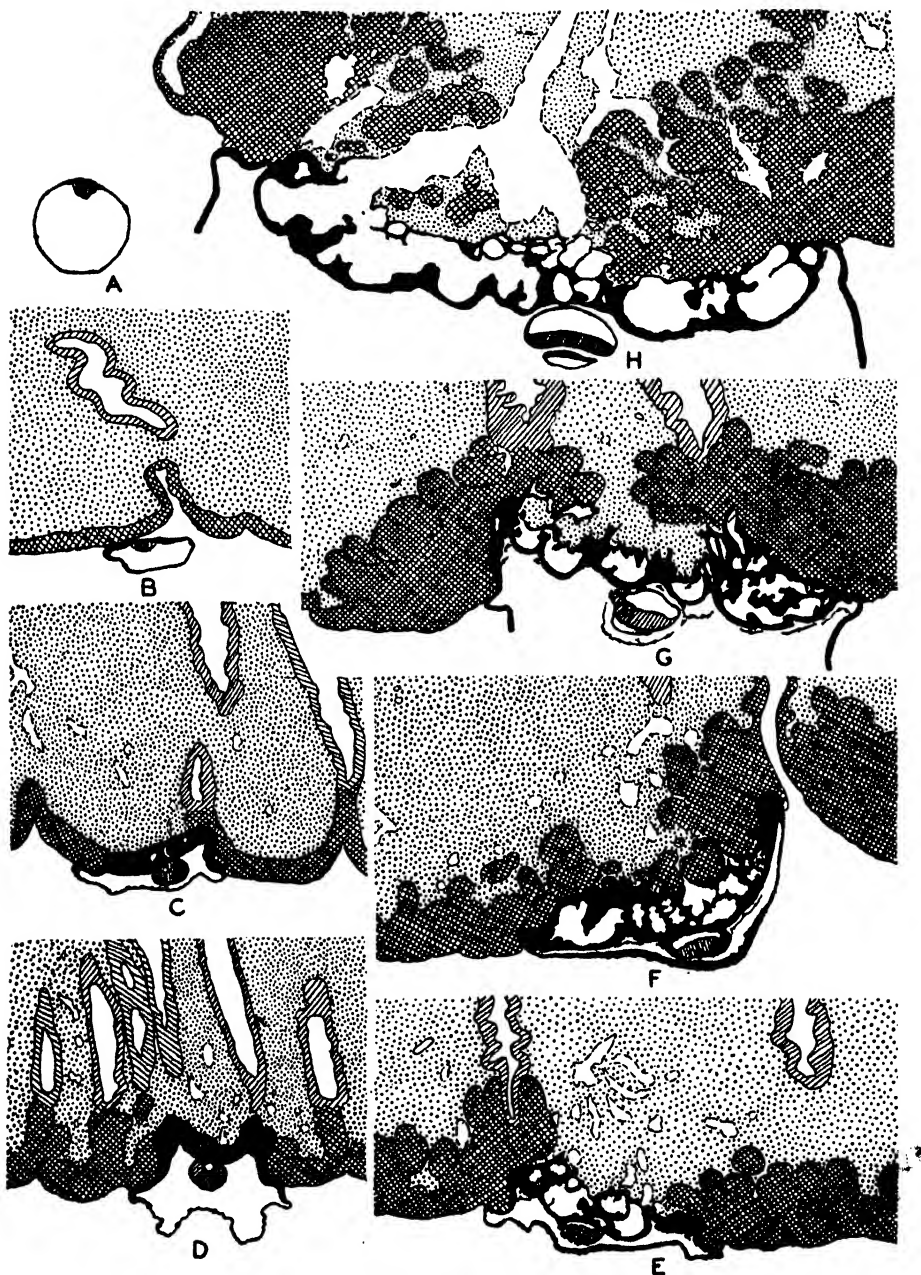


FIG. 1. Drawings illustrating the enormous growth that occurs in the trophoblastic wall (solid black) of the ovum in the four days following its parasitic attachment to the uterus. Tissue materials are necessary for such growth and these are supplied by the luxuriant uterine epithelium and the plasma and blood cells of the adjacent tissues. Previous to attachment there is very little actual increase in the mass of the ovum. These eight stages are all from monkey embryos shown at the same enlargement ($\times 75$). Their ages are as follows: A, 9 days; B, 9 days; C, 10 days; D, 10 days; E, 10½ days; F, 11 days; G, 12 days; H, 13 days.

No. 33). The villous stage begins about the 15th day and progresses to the completion of the placenta, the most important features of which can be seen already on the 35th day.

YOLK-SAC AND GUT ENDODERM

Following the attachment of the ovum on the ninth and tenth days we can speak of the third chapter in its development. With the auxiliary parts of the ovum well on their way to differentiation there is an awakening of the cells that are to form the embryo proper. This awakening is expressed by their increase in number and by their orientation and arrangement into an ectodermal disk or embryo disk. In this process the disk becomes set off, both dorsally and ventrally, by fluid-containing spaces from the abutting auxiliary tissues. The exact time relationships vary a little in different specimens and still more so in different mammals, so that in the early stages the appearance at the embryonic pole may be quite different, but apparently the underlying principles remain the same.

During the past year the studies of the writer have been directed more especially to the fluid space which develops ventral to the embryonic disk. Whereas the dorsal space enlarges to become the amnion, the ventral space enlarges to become the combined gut and yolk-sac cavity. The yolk-sac is definitely something more than an embryonic vestige. Furthermore it does not bud off from the inner cell mass in the form of a solid clump of cells, thereafter acquiring a central cavity, as had been supposed. Nor is it at any time an intrinsic part of, or homogeneous with, the gut tract. Instead our specimens show us that the earliest cells of the yolk-sac are differentiated from the primitive endoderm as a thin membrane between which and the gut endoderm there arises the conjoint yolk-sac cavity and gut cavity.

This cavity ventral to the embryo disk is therefore dual in origin. It is bordered on its dorsal part by cells that are to form the gut endoderm, an induced product or migratory element from the disk itself; whereas the space on its ventral part is bordered by the yolk-sac endoderm, which is a derivative of the primitive endoderm and is in fact an auxiliary tissue. The gut and yolk-sac are thus different in origin and are always abruptly demarcated from each other. The one becomes a definite part of the embryo and the other is an auxiliary organ which in primates plays a temporary but apparently very essential rôle in the metabolism of the embryo up to that time when its functions are taken over by the placenta, a much more elaborate and efficient organ. Thereafter the yolk-sac regresses, although we can usually find its degenerate remnants attached to the fetal membranes at birth.

YOUNG HUMAN EMBRYOS

Among the publications in the last number, volume 27, of the *Contributions* are three accounts of presomite human embryos. This early period of human development is imperfectly known because of the scarcity of well-preserved normal specimens of that age, upon which our understanding must be built. One of these specimens is that of Dr. J. I. Brewer studied in the Anatomical Laboratory of the University of Chicago. This 15-day

specimen is certainly normal and is in a good state of preservation and is destined to take its place as a standard of orientation in the procession of stages through which the human embryo passes in its development.

A slightly younger specimen has been studied in this laboratory by Dr. E. M. Ramsey. This specimen, known as the Yale Embryo, is estimated to be between 13 and 14 days old. It was obtained at autopsy and a sufficiently large block could be made to show fully the relations of the embryo to the uterine wall. Neither this nor the Brewer specimen has the perfection in histological detail that we are able to secure in our macaque embryos, and neither of them can be relied upon for some of the problems that involve finer cytology and intercellular reactions. The student of human embryology, however, is accustomed to such deficiencies and has been able to piece together his story from specimens, some of which are much less perfect than these. It is to be remembered that at the end of the second week even the gross general anatomy of the human embryo is still more or less obscure.

Among other things Dr. Ramsey analyzes the phenomenon of blood-sinus formation around the newly implanted ovum. The Yale specimen illustrates this particularly well and apparently it always occurs in normal specimens as soon as decidua appears. The sinuses are found to consist of localized dilatations of precapillary venules and their formation is an expression of the marked response that occurs in the endometrial vessels under varying hormonal and environmental conditions. Whether such localized allocations of blood plasma and red cells serve a nutritional function for the ovum or whether the sinuses are a means of lowering blood pressure in the vessels communicating with the lacunæ, thereby shielding the embryo from pressure extrusion, remains to be determined. Perhaps the most important part of Dr. Ramsey's study is her analysis of trophoblast development, and her conclusion that there is a normal correlation between it and the decidua and the embryo proper. With the normal variation in these correlations established one is then in a position to recognize the abnormal. It is also noted that it is normal for the trophoblast to develop more luxuriantly on the deeper hemisphere of the ovum where the food is more abundant than on the side toward the uterine cavity. This is responsible for the apparent invasion inward. Besides the correlated growth of the trophoblast relative to other things, there is a regulation of its differentiation into syncytium on the surface and into primitive mesoblast on the inner side, the more primitive cytotrophoblast, later known as Langhans cells, being the germinal bed for both of them. Normally a balance is maintained between these elements. The occurrence of an imbalance between them in a specimen is evidence that it is pathological. Dr. Ramsey illustrates this by a specimen from the Carnegie Collection in which the supply of parent cytotrophoblast is exhausted, being wholly converted into mesoblast on one side and syncytium on the other.

The occurrence of "syncytial wandering cells" in the above specimen has given Dr. Ramsey an opportunity to analyze their origin. There is some evidence that these are not fetal cells but are transformed stroma cells, which are in the process of being converted into pabulum for the advancing trophoblast. On that basis the multinuclear or giant cell character could be re-

garded as an expression of degeneration. On the other hand, the distribution of the cells and the absence of other signs of degeneration leave the matter in some doubt. Dr. Ramsey's study of this phenomenon serves to call attention to a phase of implantation that has been largely overlooked.

A third human embryo, younger than either of the former, has been studied by Dr. E. Scipiades, Jr., of Budapest, a guest of this laboratory as an exchange student of the Institution of International Education. This specimen carries special interest because of an associated clinical history of hormone and "small dose" X-ray treatment for sterility. The embryo was discovered in curettage material and fortunately the sections pass through the ovum in a direction that discloses the implantation details. The trophoblast is primitive in character and as yet there are no villi. This places the specimen in the group of very early ones.

ORGANOGENESIS

The studies of Dr. E. H. Norris on the parathyroid and lateral thyroid glands will already be familiar to the readers of our embryological reports. There is now to be added to these a reference to his study of the human thymus gland, to which his investigations were extended. Part of his work was done on the embryological collection in Dr. Jackson's laboratory and part on our own collection.

In his study of the morphogenesis of the thymus Dr. Norris comes to conclusions which diverge somewhat from those of Dr. Weller, who also had worked in our laboratory and on the same material. This is wholesome and tends eventually to bring us nearer to the correct solutions of these questions. A point emphasized is the cervical sinus, which Dr. Norris concludes to be the primordium of the primitive thymic cortex and the source of Hassall's corpuscles, two very important assignments. Dr. Weller had concluded that the cervical sinus is a product of the mechanical exigencies of the region and is influenced by, rather than being the cause of, the development of the thymus. It is clear that much study is still needed throughout the region of the branchial pouches before we can unravel its many factors in development. It may be that some help can be obtained through experiment. The branchial clefts have been so heavily loaded with the philosophy of recapitulation that it is difficult to separate out what is the real gill-cleft phenomenon from what is the expression of other developmental factors of the region. It is possible that recapitulation in our ways of thinking is more inexorable than it is in the development of the embryo.

In his conclusions Dr. Norris derives the epithelial elements of the human thymus from two distinct sources both of which are within the third branchial complex. These two sources make it an ectodermal-endodermal structure. The ectodermal source is the cervical sinus, which provides the primitive thymic cortex and the Hassall's corpuscles, as noted above. The endodermal thymus, arising from the third endodermal branchial pouch, gives origin to the syncytial cytotreticulum of the gland. The thymic lymphocytes he finds to be of mesenchymal origin, secondarily invading the gland. Other elements of gland reticulum are derived from connective tissue cells in the adventitia of vessels and from the gland capsule.

Embryologists have utilized the somites very largely as a topographical scale against which the levels of the body are oriented. One difficulty has been the determination of the first or most oral somite, with which they must begin their count. There has been an uncertainty as to whether the first somite of a later stage is the same as the first somite of the earlier stages; that is, are new somites added in front or perhaps does the original first somite disappear? Either of these events would alter the count. An important study covering a survey of these occipital somites in a large number of human embryos has been made by Dr. L. B. Arey of Northwestern University, and the results were reported in the last volume of the *Contributions to Embryology*. He finds that the first pair of somites usually undergo regression both in size and in structure. By tracing this regression he concludes that dedifferentiation plays a considerable part in the process. The regression may be slow in some cases but usually in embryos of more than 20 somites the first remaining pair are actually second somites. Retarded differentiation and beginning regression can be made out as early as embryos of between 5 and 9 somites. For students of embryonic anatomy Dr. Arey's careful work in this field will be of importance. Also it adds to the general principles of development an instance of over-induction, eventually corrected by the lack of supporting stimuli.

In studying the anatomy of the whale fetus Dr. R. Walmsley has covered a field in which comparatively little systematic work had been done. Although of peculiar interest because of its high degree of specialization, the adult animal from its very size and its inaccessibility has rarely been available for study except in its skeletal form. In the fetus some of the difficulties are obviated and the opportunity of studying four fetal specimens has been well utilized by Dr. Walmsley not only to cover the fetal stages but through them to interpret the conditions and problems of the adult. His oldest specimen was a mid-term fetus, and the other three fell within the first half of pregnancy.

The respiratory mechanisms of the whale in adaptation to its habits of submergence have been of great interest to the anatomist and they have resulted in highly specialized structures that are foreign to other mammals. The most striking peculiarities of the whale, however, are found in its vascular system. Dr. Walmsley's investigations were largely concerned with this system. He made a systematic study of the blood vessels throughout the whole body, both as to their gross anatomy and as to their histology. A striking generalized characteristic of the arteries was the breaking up of what in other mammals would be a single trunk into a series of collateral vessels, a condition adapted to a large volume of total blood together with a low blood pressure. The feature of greatest interest was found to be the *retia mirabilia*, especially the thoracic, which is associated with decrease in lung volume during submergence, and the cerebrospinal retia, which serves as buffer interposed between the arteries of the main parts of the body and those intrinsic to the central nervous system. Dr. Walmsley concludes that these peculiarities of the whale vascular system are not provisions against a possible shortage of oxygen, for apparently such a shortage does not occur. Instead, this highly specialized system is an adaptation to the differences

of surface pressure under which their mode of life requires them to live. It is thus understood why these specializations are more elaborate in the adult than in the fetus and are largest in whales that can remain submerged longest.

PHYSIOLOGY OF THE EMBRYO

SECRETION IN THE FETAL CHORIOID PLEXUS

Continuing his studies on the origin of function of the chorioid plexus in the fetal brain, Dr. L. B. Flexner with the cooperation of Dr. R. D. Stiehler has been able to show that the appearance of secretory activity of this plexus is correlated with the development of a difference of potential between stroma and epithelium and the initiation of an electric current between the two tissues. It had previously been shown that cerebrospinal fluid changes from an ultrafiltrate to a secretion at the end of the first third of pregnancy in the pig. In the new studies attention is turned to the biochemical changes that occur in the plexus at this transition period, when the plexus is changing from a passive state to an active chemical machine.

For determining the potentials of epithelium and stroma use was made of oxidation-reduction indicators and it was found that in the pre-secretory period the epithelium and stroma of the plexus have the same potential. With the onset of secretion, however, the potential of the epithelium rises somewhat and the potential of the stroma falls markedly until there is a potential difference of 0.10 volt. This difference increases until in the last third of the gestation period it amounts to 0.23 volt.

In the secretory plexus, in addition to the difference of potential between epithelium and stroma it was also found that the basement membrane conducts electrons. The electric current so established between epithelium and stroma explains the selective transference of acid and basic dyes across the basement membrane. In the pre-secretory plexus, since there is no difference of potential between epithelium and stroma, there is no electric current and consequently no selective transference of dyes.

In explanation of the changes in potentials of epithelium and stroma, it is pointed out by Dr. Flexner that in the pre-secretory period indophenol oxidase is in low concentration and equally distributed between epithelium and stroma. As secretion begins this oxidase disappears from the stroma and is found in much higher concentration in the epithelium. Indophenol oxidase activates molecular oxygen for biological oxidations and in its presence, other factors being equal, the potential level of a tissue is raised. Thus these changes in potential seem to hinge on the distribution of indophenol oxidase.

In his studies of the biological processes underlying the formation of cerebrospinal fluid by the chorioid plexus, Dr. Flexner has made an analysis of the thermodynamics of ultrafiltration and has verified his theoretical deductions by experiments with sucrose solutions and to some extent with colloidal solutions. In this way he has obtained criteria for distinguishing whether the cerebrospinal fluid is a dialysate in equilibrium with the blood plasma, or an ultrafiltrate of the blood plasma, or a true secretion involving energy

expenditure by living cells. In this work Dr. Flexner has found himself in the enviable position of the biologist who on reaching one of his frontiers is able to help himself out by making use of some of the pathways that have been developed in a neighboring discipline.

CHROMOSOME STUDIES

DEVELOPMENT OF THE SALIVARY GLAND CHROMOSOMES

Because of their unique interest an investigation has been made by Dr. J. B. Buck of the embryology of the giant chromosomes which are found in the larval salivary glands of Diptera. Using *Sciara* larvæ he has traced the steps of transformation of these chromosomes from their original state, when in size and appearance they are like ordinary somatic chromosomes, until they attain their enormous size and typical banded appearance. In doing this he made measurements of the chromosomes, nuclei, cells, glands, and larvæ in the living state. The finer morphology of the chromosomes was studied on fixed material for each stage of development.

It was found that the salivary gland attains its definitive number of cells soon after it arises in the embryo within the egg. Its subsequent growth is due entirely to increase in cell size and the greater part of this growth occurs in the late larval stages. What is true of the cell is also true of the nucleus and then in turn of the chromosomes, which compose 90 per cent of the nuclear volume. The nuclear volume doubles every $1\frac{1}{4}$ days during the period of the 4th to the 17th days, from which time to the beginning of pupation it becomes progressively less.

As to the structure of the chromosomes, it is found that in the early embryonic gland homologous chromosomes are paired, and are merely short slender threads. From the outset, however, each thread exhibits enlargements which correspond to those of its homologue. Each of the threads soon splits into two threads, retaining however some cross-connections. The homologues are thus doubled and shortly before the larva hatches from the egg these doubled homologues begin to twist or coil about each other and fusion between homologous regions begins. There is thus produced a four-stranded helically coiled flattened chromosome as early as $6\frac{1}{2}$ days after the egg is laid. Each synapsed pair of doubled homologues soon appears as a slender cylindrical and much elongated strand, showing diffuse cross-bands at intervals which foreshadow the "banding" of the fully developed salivary chromosome. During the succeeding larval stages the chromosomes greatly increase in diameter, the banding becomes more pronounced, and the coiling reaches its maximum. Before pupation the coiling relaxes and the chromosomes become straighter, and this is the period of their greatest growth. As pupation sets in, however, these giant chromosomes begin to regress and finally during the pupal stage the larval salivary glands undergo histolytic degeneration.

In reference to the development of the banding, Dr. Buck found that the first ones to appear represent the heaviest bands of the definitive chromosome. They remain relatively unaltered during development, though they tend to darken and some of them separate into doublets. The new, light

bands, which become visible as development proceeds, appear in the lengthening spaces between the heavier bands. They apparently do not split off from the latter.

This investigation is being carried further but already it has uncovered some very essential features which will need to be reckoned with by the chromosome cytologists and by the searchers for the gene.

CHROMOSOME PUFFING AND CHROMOSOME KNOTS

In his studies on the giant salivary gland chromosomes in *Sciara* Dr. C. W. Metz has turned his attention to the phenomenon of "puffing" and the structure of such regions. Instead of the characteristic banded structure the chromosome may vary in certain particular regions by becoming greatly expanded or "puffed." In such an area it is uniformly granular, resembling cytoplasm as seen in fixed preparations. It is evident that the segment involved has been increased in volume and that the increase is in the form of small achromatic droplets. Intermediate degrees of "puffing" show bands in various degrees of disintegration. Dr. Metz points out that the material in these "puffed" regions is perhaps comparable to that of the "chromocenter" in *Drosophila*, and if it is we must conclude that the "chromocenter" is not inert. From the study of living cells in tissue culture we have learned the wide range in form which cells may undergo with different physiological states, and our recent observations on chromosomes and their chromatin content tend to show that here, too, we have structures that are delicately responsive to the state of the nucleus and the circumstances of the environment.

In a former report reference was made to the evidence obtained by Dr. Metz of the presence of an insulating sheath surrounding the individual chromosome. In a review of the occurrence of chromosomal knots he adds further evidence of the existence of such a sheath. Simple knots are occasionally found midway in the giant salivary gland chromosomes of *Sciara*. It is evident that they arise early while the chromosomes are still small threads, but since the knots always involve both homologues they must have formed after the homologues had fused. The principal growth of the chromosome occurs after the completion of the knot, and this tends to make the knot a snug one. A knot can form only in the presence of free movement of the chromosome. At its initiation there must be a loop and the sliding of one part over another. That fusion does not result during the process is explained by Dr. Metz by hypothesizing an insulating sheath. As the chromosome becomes thicker and the knot becomes tighter it would appear on mechanical grounds that the segments involved would become deleted or, if the tenseness sufficiently overcame the protection of the sheath, fusion would follow and an inversion of segments would occur. Such events would explain some of the well-known genetic experiences.

MULTIPLICATION AND REDUCTION OF CHROMOSOME GROUPS

Last year an account was given of the studies of Dr. C. A. Berger on the multiple chromosome complexes found in the larval ileum of the mosquito, where repeated division of the chromosomes occurs without division of the

nucleus. That is, during the larval period the epithelial cells of the ileum grow by increase in cell size to three or four times their original volume without an increase in the number of cells. It is not until metamorphosis that division of the cells occurs. As metamorphosis progresses these cells repeatedly divide with corresponding decrease in their size and in the number of chromosomes until we come to the relatively small nuclei of the rebuilt imaginal ileum with its normal diploid number of 6 chromosomes. Here we have compounding of chromosomes which may well be compared to that seen in the giant salivary gland chromosomes. Since last year Dr. Berger's paper has been completed in its final form and has been published in volume 27 of the *Contributions to Embryology*.

GENETIC STUDIES

GENETIC UNITS

In the last Year Book reference was made to the difficulties met in distinguishing between genic and non-genic material in the chromosome. Dr. C. W. Metz has continued his consideration of this problem and at the end of the additional year he still is unable to place his finger on the gene though in the meantime he has made further additions to our knowledge of the finer anatomy of the chromosome.

The problem has been approached from another aspect, namely, a study has been made of small chromosomal deficiencies, which are either lost or acquired as units and therefore might represent genes. Dr. Metz has thus attempted to identify the smallest possible structure that, as a unit, may be lost or acquired, and at the same time to determine the nature of this structure in terms of its visible chromatic and achromatic chromosomal constituents. For his material he has utilized *Sciara ocellaris*, which is particularly favorable in that it is characterized by various small chromosomal deficiencies which may be found in ordinary stocks without radiation. These deficiencies appear to be widely distributed in nature.

The general trend of evidence from the salivary gland chromosomes of this form is that any of the transverse disks, including even the thin ones, is divisible into two or more disks sufficiently independent so that one may be lost without the other, or a similar one may be acquired. Dr. Metz has analyzed in detail eight examples of this kind of deficiency and has attempted to determine: (1) what is the smallest unit that can be detected as a deficiency? (2) what is the composition of this unit in terms of chromatic and achromatic materials? and (3) what is thereby revealed as to the relationship of the chromatic disks to the achromatic material? He found that these questions could be answered at least in part. The smallest unit loss or acquisition involves a single chromatic disk and the layer of achromatic material on one side of it. As to the relationship of the chromatic disk to the chromatic material matters remain uncertain. The evidence points toward the chromatic rather than the achromatic materials as the genetically important constituents. Both exhibit considerable variation in appearance, but apparently the variation in the chromatic disks is largely due to variations in the amount and distribution of achromatic materials. Dr. Metz

concludes that the heavy walled droplets, thought by some to represent unit genes or chromomeres, are probably not unit structures and do not represent unit loci.

OBSERVATIONS ON *SCIARA* HYBRIDS

For purpose of genetic and cytological studies several wild strains of *Sciara* have been brought into the laboratory from various localities. Dr. Metz has found among this material a new species of *Sciara* (*S. reynoldsi*) which hybridizes with one of the more common laboratory species (*S. ocellaris*). The two species possess definite morphological distinctions. In general appearance, however, the two species are so nearly identical that their discreteness was not noted until it was found that many of the cross-matings between them failed to give offspring and also that their salivary gland chromosomes differ in pattern. Because of the importance of this new species for genetic studies a taxonomic description of it has been published by Dr. Metz for the information of other workers.

Preliminary hybridization studies of the above two species already have been made by Dr. Metz and Mrs. E. G. Lawrence. Among the results obtained by them are the following: (1) no offspring are secured from matings of *S. reynoldsi* ♀ × *S. ocellaris* ♂; (2) *S. ocellaris* ♀ × *S. reynoldsi* ♂ give vigorous, viable offspring in large numbers; (3) apparently all hybrid females are sterile; (4) hybrid males are not sterile; when mated with *ocellaris* females offspring were obtained in eight out of ten matings; (5) many of the hybrids are gynandromorphs, representing various types of mosaics of male and female parts; (6) abnormal gonads are found very frequently; (7) when yellow (a sex-linked mutant character) *ocellaris* females were mated to wild-type *reynoldsi* males, the daughters were found to be "wild-type" and the sons all "yellow"; (8) the males thus transmit only the chromosomes received from their mothers and they thus behave genetically as if they were pure *S. ocellaris*; (9) the original cross and backcross matings are successful only when *ocellaris* is used as the female parent; (10) the hybrids tend to be intermediate between the two parents in respect to taxonomic characters; (11) the metaphase chromosome groups of the two species appear to be alike, each consisting of three similar pairs of rod-like chromosomes and one pair V-shaped; (12) in the salivary glands of hybrids the chromosomes are associated in symmetrical pairs, but complete fusion is found only in a few short regions. In their publication the interesting structure and incomplete fusion of the salivary gland chromosomes of these hybrids are fully illustrated.

NEW MUTANTS IN *SCIARA*

Six new mutant characters in *Sciara* which have been found in this laboratory among descendants of flies which had been exposed to radium, along with two mutants which appear to be identical or reciprocal to two of them, have been studied by Miss H. V. Crouse and Dr. H. Smith-Stocking. In each instance the origin and description of the character and its genetic behavior have been completely analyzed by them. They have found that the character "stop" is an autosomal dominant in *S. coprophila*, involving a translocation between chromosomes II and IV. "Yellow" is a sex-linked

recessive in *S. ocellaris*. This character has already been referred to in connection with the hybrids described above. Of the four mutations found in *S. reynoldsi*, "puff" and "vesiculated" are autosomal dominants that are lethal when homozygous. They may prove to be reciprocal or perhaps identical. "Jagged" is a sex-linked dominant that is lethal when homozygous. "Ruffled" is a sex-linked dominant and closely linked to it is "Yellow," a sex-linked recessive. The "yellow" mutations of *S. reynoldsi* and *S. ocellaris* appear to be reciprocal. These investigators conclude that the genetic behavior of these mutant characters is proof of selective segregation in *S. ocellaris* and *S. reynoldsi*.

CHEMISTRY OF BODY TISSUES

IMPROVED METHODS FOR HISTOCHEMICAL ANALYSIS OF TISSUES

Dr. I. Gersh has adapted the Altman freezing-drying technique for the identification of the presence of chloride, phosphate-carbonate, and potassium in muscle tissue. In this way he avoids diffusion of water-soluble substances which had vitiated the studies of earlier workers. By embedding the frozen-dried material in paraffin and sectioning at known thickness the distribution of the substances can be studied and access of subsequent reagents is facilitated. The paraffin is removed by petroleum ether and this allows silver reagents to penetrate the sections. Silver nitrate solutions were used to precipitate chloride ions, alone or together with phosphate and carbonate ions. The precipitated silver salts were reduced by exposure to an arc light. Potassium was made visible by the use of sodium cobaltinitrite. The details of the procedure as worked out by Dr. Gersh will not be given here. They have, however, been made available to other investigators in the published account of his investigation.

As regards chloride, Dr. Gersh was not able to find any in the muscle cells of the frog sartorius. It was present, however, in the interstitial and collagenous connective tissue. When the muscle chloride concentration was decreased or increased by suitable manipulation there was a corresponding decrease or increase in the amount of chloride visible in the connective tissue spaces. In all cases there was more visible chloride present in collagenous connective tissue than in reticular connective tissue.

In all the muscles examined phosphate-carbonate was seen in the muscle cell, as well as in the connective tissue surrounding it. It was determined by the difference between the color intensities produced by two reagents, one an acidified silver nitrate nearly saturated with silver chloride and the other a silver nitrate nearly saturated with silver chloride and silver phosphate. It was found that the distribution of phosphate-carbonate is uniform throughout the cytoplasm and does not have a linear arrangement as described by earlier histochemists.

Potassium was determined with sodium cobaltinitrite at a low temperature. The crystals representing potassium are seen uniformly throughout the whole cell cytoplasm. There is some variation in the density with which the cell is packed but it is slight. Perhaps the variations are not easily seen because the crystals are so numerous. Like phosphate-carbonate, potassium

is distributed uniformly in the muscle fiber, without relation to longitudinal or transverse striations. Dr. Gersh in these observations has been able to demonstrate the intracellular distribution of these four ions in striated muscle fibers, concerning which we have heretofore depended on deductions and assumptions. He confirms by direct histochemical methods the fact that potassium is present in very large amounts in the cytoplasm, that phosphate-carbonate is present in moderate amounts, and that chloride is completely absent.

DISTRIBUTION OF CHLORIDE IN GASTRIC MUCOSA

The methods which we have seen developed in the preceding paragraphs provide a technique which is sensitive, specific, and devoid of diffusion errors. With it Dr. Gersh has attempted to clarify the problem of the site and mode of formation of hydrochloric acid in the stomach. The gastric mucosa of dogs was studied during the resting phase and during the height of activity. He found that during rest chloride is absent from the cytoplasm of all gland cells. Traces of it are, however, present in the secretion granules of the zymogenic gland cells. Chloride is found in the lumen of the gland and in still larger amounts in the gastric pits into which the gland lumina empty. Furthermore, it is found evenly distributed throughout the connective tissue spaces of the mucosa and submucosa.

In the actively secreting mucosa the distribution of chloride was found to be essentially the same as in the resting stage. It was found in the same places but was present in greater amounts. More chloride is visible in the cytoplasmic inclusions of the zymogenic cells and the spaces of the connective tissue. The cytoplasm of all the glandular cells is free of chloride, just as was seen in muscle fibers.

Dr. Gersh finds himself unable to explain the presence of chloride in the secretion granules of the zymogenic cells. Its presence in the connective tissue spaces is naturally correlated with greater amounts of chloride-containing tissue fluid and lymph, formed during glandular activity. It is suggested that the protein chloride is extruded from the parietal cells as rapidly as it is formed and none of the compound is stored in the cytoplasm. It may still be true that the parietal cell is the one whose specific activity results in the secretion of hydrochloric acid, even though our present methods fail to detect it in its early secretory phases.

HISTOCHEMISTRY OF THE FATE OF COLLOIDAL CALCIUM PHOSPHATE

A series of experiments have been conducted by Dr. I. Gersh dealing with the metabolism of calcium and phosphorus in the blood. Following intravenous injections of rats and dogs, in some cases with calcium and phosphate salts, and in other cases with colloidal calcium phosphate suspended in horse serum, he was able to follow the mechanism existing for the rapid removal of excess colloidal calcium phosphate from the blood, namely, by the phagocytosis of the particles by the macrophages of the liver and spleen and to a less extent of the bone marrow. The phagocytosed particles are retained by the macrophages a relatively short time and are then liberated. The whole mechanism is a transitory one. His experiments show that the

degree of phagocytosis is influenced by variations in the amount of colloidal compound present in the blood stream. The macrophages of the lymph nodes take no part in this, as long as the colloidal particles are confined to the blood stream. If, however, colloidal calcium phosphate is injected subcutaneously or into the muscles so that it enters the lymph and tissue fluid, phagocytosis in lymph nodes may then take place.

As has been said, the colloidal particles of calcium phosphate are retained in the cytoplasm of the macrophages but a short time and are then liberated. This subsequent liberation of the calcium and phosphate into the blood appears to be responsible for the delayed rise in serum calcium which is experienced particularly after the intravenous administration of phosphate. It is proposed by Dr. Gersh that the granules of calcium phosphate in the cells may be turned into the constituent calcium and phosphate ions, which leave the cells as fast as they are formed. While this process continues the calcium and phosphate in concentrations in the blood plasma are reduced by their passage through the capillaries into the urine, feces, and tissue fluid.

The histochemical method used by Dr. Gersh for testing the content of phosphate in the sections revealed it as a precipitate of black or brown granules in the phagocytic cells. For testing the presence of calcium in the sections, after the freezing-drying-embedding technique and the removal of the petroleum ether, they are treated with a water solution of sodium alizarine sulfonate, which is drained off and replaced by chemically pure glycerine. Calcium in such sections appears as an orange color and the granules are less numerous and not as discretely separated as after the application of the silver reagent. With this much accomplished it is not too much to hope that a test may be found that will reveal these substances differentially in living cells.

TISSUE CULTURE

LYMPHOCYTES AND MONOCYTES

Using lymph node explants, Dr. W. H. Lewis has studied the emigration from them of lymphocytes and small monocytes. As they first make their appearance, they are about the same size and could be mistaken for each other. Dr. Lewis finds, however, that they are two different types of cells and that the lymphocyte does not become transformed into the monocyte. The two types can be distinguished by their mode of locomotion as well as by their morphological details. The lymphocytes may divide but they rarely live more than a few days. The monocytes, in contrast, increase in size, multiply, and survive for many days.

CULTIVATION OF CANCER CELLS

A review has been published by Dr. W. H. Lewis of his studies on the cultivation and cytology of cancer cells. This investigation has extended over a period of several years and includes observations on 17 rat sarcomas and 160 dibenzanthracene mouse sarcomas. He confirms his previously expressed opinion that cancer cells are permanently altered cells. They are new types, derived from normal and usually healthy ones, which have been permanently altered by environmental influences or various sorts of agents.

After the normal cells have undergone the initial alteration into malignant cells the special environmental influences or agents which produced them are no longer necessary for the maintenance of their peculiarities.

Dr. Lewis finds that in tissue cultures the malignant cells are visibly different from normal ones and from each other. They retain their peculiar characteristics from one generation to another when serially transplanted from animal to animal and for months or even years. From six of the tumors malignant cells were cultivated "in glass" for two to over four years. In that way pure colonies of the malignant cells were obtained which retained both their cultural characteristics and their malignancy. When inoculated into animals typical tumors resulted. From these in turn pure colonies of characteristic malignant cells were secured and these also produced typical tumors.

In the dibenzanthracene mouse sarcomas there were not as many varieties of malignant cells as in the rat tumors, nor were they as different from one another as were those of the rat sarcomas. The malignant cells from them were, however, visibly different from normal ones, and they could be followed in subsequent generations by comparison of photographs of the primary tumors with those of descendent cultures.

In roller tube cultures where cells have been carried on for three or four months, there were found many large multinucleated giant cells of skeletal muscle origin in addition to the fibroblast type of malignant cells. Further study has revealed that these giant cells are muscle cells altered by the invasion of the muscle by malignant cells but are not themselves malignant.

TRANSPLANTABILITY OF INDUCED AND SPONTANEOUS TUMORS

A study of the transplantability of sarcoma tumors induced by dibenzanthracene and of spontaneous mammary gland carcinomata in four pure inbred strains of mice has been made by Mrs. M. R. Lewis and Mrs. E. G. Lichtenstein. They found that every one of the 200 tumors they induced in their four inbred strains proved to be transplantable into all the mice of the strain in which the tumor arose. Out of 123 tumors which were transplanted to alien strains only 9 grew, that is, 114 proved to be strain specific. This resistance of mice of one strain to tumors transplanted from another strain was referred to in a previous report (Year Book No. 35). It was also reported at that time that this resistance could be broken down. Since then more has been learned as to the range within which this can occur. Fourteen of the tumors that were strain specific when implanted in normal young mice of alien strains lost their strain specificity when they grew in a repeatedly implanted host of an alien strain, so that they were thereafter transplantable not only into mice of their original strain and of the treated strain, but also into mice of other strains.

In the study of 80 spontaneous mammary gland tumors it was found that they not only were strain specific but also largely retained this specificity even though repeated inoculations were made into hosts of alien strains. There were a few exceptions in which the tumors became transplantable into mice of a closely related strain. Where mice already had a spontaneous mammary gland tumor, they were not immune to the development of addi-

tional spontaneous mammary tumors. Some of the mice developed as many as five mammary gland tumors during the course of two months. These same animals, however, were somewhat refractory to the growth of similar tumors grafted from other mice even though of the same strain. The individuality of tumor growth was well shown in a series of experiments in which a carcinoma was implanted on one side of a mouse and a sarcoma on the other. Both tumors grew in such cases and were transplanted through many generations in this manner. They each retained their own characteristics, and microscopic examination showed one to be an adenocarcinoma and the other a large spindle cell sarcoma.

A USEFUL CULTURE TISSUE

It has been found by Dr. W. Mendelsohn that explants from the testicle of the adult rabbit can be successfully grown in roller tube cultures. From them he obtains extensive growths of epithelium suitable for testing the viability of epithelial cells in the presence of arsenical drugs, hormones, toxins, and viruses. These growths also are suitable as a culture medium for the growth of *Spirochæta pallida*.

Fragments of the testicle are distributed inside the tubes and held in place by heparinized chicken plasma. As a nutrient medium rabbit serum is used with a balanced salt solution. Locke solution can be substituted for the balanced salt solution. After seven days areas of liquefaction occur near the explants but these can be repaired by clots of chicken plasma and fresh nutrient fluid substituted for the old. In this way the cultures can be maintained three weeks or longer if desired. There appears to be no difficulty in making permanent mounts of such growths.

The first outgrowths from the explants are chiefly fibroblasts and endothelial cells. Later broad sheets of germinal epithelium extend from the convoluted tubules. Occasionally Sertoli cells are seen. Apparently spermatozoa may undergo maturation from the spermatocytes in this roller tube culture.

STUDIES OF THE PITUITARY GLAND

TISSUE CULTURES OF THE HYPOPHYSIS

The study of the pituitary gland in tissue culture has been followed for several years by Mrs. M. R. Lewis. She found that such cultures taken from all the ordinary laboratory animals grow rapidly and abundantly, regardless of the age of the animal from which the gland is obtained. They grow particularly well in tube cultures. The cells retain their differentiation and continue to form their specific granules, though the granules are fewer than in the original tissue.

It was found that cells grown in cultures for as long as fifty days continued to produce blood-pressure-raising and melanophore-expanding hormones. In an effort to correlate cell types with specific hormones animals were sought in which cell types were so segregated that particular regions could be dissected out for transplantation. In the mouse the pars intermedia is free of pars nervosa tissue. In the chicken and armadillo the pars nervosa is free of other lobe tissue, whereas in the dogfish and skate the

pituitary cells are segregated into six separate lobes. The melanophore hormone was located in two of these latter lobes and continued to form in cultures. Apparently tissue culture affords a valuable tool for determining specific functions of the pituitary cell groups, at least in the case of the hormones belonging to the posterior lobe. The hormones of the anterior lobe are more complicated in their activity and this has made them more difficult to identify. A review of the present status of her studies was given by Mrs. Lewis before the Association for Research in Nervous and Mental Disease.

CYTOLOGY OF THE HYPOPHYSIS

In a previous Year Book an account was given of the studies of Dr. I. Gersh on the relation of the histological structure of the posterior lobe of the hypophysis and the pressor, oxytocic, and antidiuretic hormones which are generally assumed to originate there. He was able to show that the hyaline bodies of Herring, which had been thought to be a secretion antecedent, are an artifact and are not present when the tissue is prepared under the best conditions. This left only neuroglia cells as the local source; unless one concluded that these three hormones were made elsewhere and transported by the blood stream and deposited through means of a special capillary permeability and stored in the posterior lobe.

During the past year further study of the parenchymatous cells of the posterior lobe in rats has led Dr. Gersh to the conclusion that some of these cells are really glandular and that they produce and secrete the antidiuretic hormone. This posterior lobe glandular cell has been found by him in a wide variety of mammals and in pigeons and in chickens. It is characterized by the presence of either granules or lipid droplets which can be seen in fresh mounts and which fill the cytoplasm and extend out into the cell processes. In the rat these droplets are rich in neutral unsaturated fats; in some animals there are no visible lipoids. A characteristic feature of this glandular cell is that it appears early in embryonic life and that the number and size of the cells and of their inclusion bodies increase throughout life, reaching their greatest prominence in rats two and a half years old. Owing to the fact that there is a normal range in the number and size of these posterior lobe glandular cells in any particular gland, Dr. Gersh was able to show that fluctuations occur within this range which are correlated with the dietary intake of water. This fluctuation could be controlled experimentally. After rats have been restricted to a relatively dry diet for a week the glandular cells are present in greater number and are larger. On the other hand when the experimentally dehydrated rats are given free access to water, the number and size of the differentiated cells promptly revert to the normal range prevailing in untreated rats. Thus Dr. Gersh establishes a significant correlation of cellular activity and morphology with the hypersecretion of antidiuretic substances, and perhaps also of oxytocic substances.

It may be added that among the parenchymatous cells of the posterior lobe there are many that are relatively undifferentiated, but which during the hyperplasia, which follows the stimulus to hypersecretion, become transformed into the fully differentiated form. The differentiated and the relatively undifferentiated varieties vary inversely in number.

NERVE TERMINATIONS IN THE POSTERIOR LOBE

Using pyridine silver preparations and fresh pituitaries of young rats perfused with methylene blue, Dr. C. McC. Brooks and Dr. I. Gersh have succeeded in demonstrating nerve fibers which pass down on the hypophyseal stalk to terminate in pericellular baskets around the glandular cells of the posterior lobe described in the preceding paragraphs. The endings almost completely enclosed the cells in a close-meshed network. The fibers belong to the hypothalamic hypophyseal tract. It was found that they are unaffected by the removal of the superior cervical ganglion, which would remove them from the category of the sympathetic chain, if that were necessary.

The demonstration of this nerve supply to the posterior lobe glandular cells gives us an explanation of the phenomena of pseudo-pregnancy, which had been recognized as requiring the transmission of nerve stimuli. It also becomes clear that section of the pituitary stalk would lead to degeneration of these terminations and an accompanying severe diabetes insipidus.

REPRODUCTIVE SYSTEM AND ENDOCRINOLOGY

THE GILFILLIN-GREGG SKIN TEST FOR PREGNANCY

A theory has been advanced that the abundant supply of prolactin in the blood of pregnant women should render these individuals immune to further injections of urinary prolactin, whereas the non-pregnant woman should be prolactin-sensitive. Were this true it would constitute a simple and economical test for pregnancy. Two guest investigators in the laboratory, Dr. S. Säglík and Dr. E. Scipiadès, Jr., have tested this technique on animals. After failing to obtain differential reactions in rats, guinea pigs, and rabbits, they made experimental injections of prolactin in a series of monkeys, in a few of them in the form of antuitrin-S and in others in the form of follutein. Here, too, the results proved negative.

For purposes of control and as a test of the potency of the hormone used on the animals, skin tests were made with follutein in pregnant and non-pregnant women. Of 19 non-pregnant women only 11 gave the postulated reaction, whereas of 23 pregnant women, whose pregnancies varied between 16 and 40 weeks, 6 reacted in a manner expected only in non-pregnant women. It is thus clear that this test is not sufficiently reliable to replace the standard Aschheim-Zondek or Friedman test.

TIME OF OVULATION

In reporting observations on the formation of uterine epithelial plaques in the process of implantation of young monkey embryos, Dr. C. G. Hartman assembled and reported his records on ovulation. Among 300 ovulations accurately diagnosed, all occurred between days 8 and 16 with the exception of 5, which fell irregularly outside that period. This seems to be a mechanism whose precision is rarely surpassed among biological phenomena.

ALLEGED BIRTH OF TRIPLETS IN THE MACAQUE

Though multiple births may occur in the rhesus monkey it has been shown by Dr. C. G. Hartman that one must be on guard against being misled

by a tendency to kidnaping that prevails among certain aggressive mother monkeys. In a case of apparent triplets it was possible for Dr. Hartman to show that two other recent mothers in the same cage had been deprived of their young, and also he obtained the conclusive evidence provided by the fact that the appropriate mother had but one recent corpus luteum.

THE ANTHROPOID OVARY

The opportunity of studying the ovaries of three gorillas, two chimpanzees, one orang-utan, and one gibbon has been well utilized by Dr. S. Sāglik, a guest of this laboratory from the Gynecological Clinic, Gülhane Hospital, Istanbul, in giving us an analytic description of the anthropoid ovary. He has also compared these ovaries with those of man and with those of the Old and New World monkeys.

Dr. Sāglik finds that primate ovaries can be arranged in a series on the basis of their general similarity to the human ovary and he arranges them as follows: orang-utan, chimpanzee, gorilla, macaque, cebus, gibbon, *Allouata*, and *Ateles*. Here then we have another organ which would call for a very different phylogenetic tree from that demanded by the skeleton.

MENSTRUATION

A study of the incidence of menstrual cycles without associated ovulation has been made by Dr. C. G. Hartman on 300 female monkeys of the Carnegie colony, concerning all of which he possessed fairly complete biological records. These animals with few exceptions were purchased from animal dealers and about one-third of them were superior specimens. Such animals ovulate either at once after arrival or at least after a few months' period of acclimatization. Another third of the animals received were inferior ones that either did not menstruate at all or menstruated without ovulation. The remaining third of the animals were intermediate in quality. They remained in excellent health but ovulated less reliably or in some instances never. This material provided Dr. Hartman with the opportunity of studying a very large number of cycles, a sufficient number to determine their principal variations. Of particular importance were his determinations of the frequency of non-ovulatory cycles.

On analyzing the non-ovulating monkeys he found that the cycles could be separated into two groups, those in which the non-ovulatory cycles may be regarded as normal, and those in which the occurrence is pathological. His records include 1000 cycles in which non-ovulatory cycles occurred during the non-breeding season, from May to September. This appears to represent normal behavior. Also non-ovulatory cycles are normal in adolescence, of which there were 240 records. Likewise in the pre-climacterium and during recovery from pregnancy and lactation non-ovulatory cycles are normal. On the other hand, in 260 animals there were 1075 cycles in which there was no ovulation and which must be classed as abnormal or pathological. Some of these animals were palpably sick, and either did not menstruate at all or menstruated without ovulating a few times before death. About 30 per cent of the animals fell in this group. Then there are some apparently healthy animals which never ovulate or else only occasionally ovulate. Of

the observed non-ovulatory cycles 17 per cent belong in each of these two groups. Some animals are unpredictable and ovulate about one-half the cycles of the breeding season. Such animals yielded a number of our finest embryos. Recently acquired animals are very likely to skip their ovulations for a time after their arrival. Some were with us two years before their ovulations started, some one year, and others began ovulating during the first year. Then among even the best animals there were some who occasionally failed to ovulate at the normal times. About 10 per cent of the non-ovulatory cycles fell in this group. From these records it is seen that the non-ovulatory cycle is a very definite thing and becomes a factor that must be reckoned with in consideration of the occurrence of sterility.

Further studies have been made by Dr. Hartman on the hormonal control of menstruation. He has found that by periods of daily administration of testosterone in a monkey which has previously been regular in its menstrual cycles the cycle can be lengthened to 38 days as against 25 to 28 days previous to the experiment. In animals which have been castrated the bleeding which usually follows within a few days was inhibited by daily administration of testosterone. Also the menstrual bleeding which in favorable animals uniformly occurs following the injection of amniotin can be inhibited over prolonged periods. Thus Dr. Hartman shows that testosterone has an action upon menstrual control closely simulating that of progestin, just as it also simulates progestin in stimulating mammary development and in inhibiting the vaginal mucosa.

At this point reference should be made to the light thrown on the menstruation problem by the studies of Dr. J. E. Markee done in cooperation with Dr. Hartman. They made transplants of endometrium according to Dr. Markee's method and were able to follow the vascular changes by direct observation. This work is now in course of final preparation for publication. It will be reviewed in full in my next report.

HORMONE INJECTIONS IN YOUNG ALLIGATORS

Before his appointment on the Johns Hopkins staff, Dr. T. R. Forbes had already, under Dr. R. K. Burns, Jr., made his experiments on the induction of a precocious development of the reproductive tract in the immature alligator by the administration of hypophyseal extracts. He had also studied the effects of female sex hormone injections (œstrone) in young alligators and found that it produced a marked hypertrophy of both ovarian and testicular cortex, along with greatly hypertrophied oviducts in the females and some development of the male vestigial müllerian ducts. This work has been published during the past year. Dr. Forbes has continued his hormone studies on the sexually immature alligator. He has investigated the effects of prolonged injections of testosterone in recently hatched animals and found them responsive to this hormone. In 14 females moderate hypertrophy of the oviducts took place, although the change in the ovaries was less definite. In the male the testes were twice as large as those of the control animals and there was definite hypertrophy of the vestigial müllerian ducts and of the penis. The wolffian ducts and the wolffian bodies were found unresponsive in both sexes to injections of these sex hormones. If we accept them as

embryonic organs that perform an essential but temporary service for the embryo it removes them from the group of reproductive organs and would explain their failure to respond to either testosterone or œstrone.

TISSUE CULTURE OF ENDOCRINE ORGANS FOR PURPOSES OF TRANSPLANTATION

Some tentative experiments have been made by Dr. G. O. Gey toward obtaining pure strains of thyroid and parathyroid cells in continuous tissue culture from which homologous grafts can be made on individuals who through deficiencies of their own need these specific endocrine secretions. Thus far a number of successful grafts of thyroid cultures have been made in dogs and also a few parathyroid grafts. The advantage of tissue culture grafts is that in this way the desired endocrine cells can be acclimated to a tissue culture medium that is composed largely of the recipients' plasma and serum, thereby increasing the probability of their survival and functional activity.

EXPERIMENTS ON CASTRATED ANIMALS

In recently castrated young male rats it has been found by Dr. J. Ball that the female hormone *estrin*, if given in daily injections of proper amounts (50 to 100 rat units), will definitely increase or completely restore their sex activity. The experiments were conducted on six male rats which were castrated at about four months old and the tests were begun two weeks later. Quantitative records were made both of their mating behavior and of their motor activity as registered by the revolving drum. The amount of hormone used was regulated by the response of the individual animal. After the castrate level of sex activity had been determined a sufficient amount of the hormone was given in daily injections to bring out an unquestionable response in each rat. From the results of these experiments Dr. Ball reached a conclusion that will be of interest to students of behavior, namely, that the function of this estrogenic hormone in the adult animal is not so much to organize the mating behavior pattern as it is to activate a pattern already laid down through other influences.

New observations have been made by Dr. C. G. Hartman on the results of castration in pregnant monkeys. Two animals castrated at the end of the third month of gestation carried their fetuses to full term. Three others castrated on the 46th, 35th, and 31st day, respectively, were progressing normally two months later. These results harmonize with the fact observed by Drs. Hartman, Corner, and Bartelmez that the corpus luteum of the rhesus monkey is active only during the first four weeks of pregnancy, at which time it markedly regresses. Theoretically its removal at any time thereafter should not interfere with the continuance of pregnancy and, as seen in these experiments, it does not.

CENTRAL NERVOUS SYSTEM

CEREBROSPINAL FLUID

In his lectures given at the University College, London, Dr. L. H. Weed pointed out the importance to many fields of anatomical investigation of intimately combining anatomical and physiological thought, and paying

equal regard to structure and to function. It was not necessary for Dr. Weed to point this out, since his own example in the study of the coverings of the brain and the specialized fluid that is contained within them had long since provided us with a brilliant demonstration of the advantage of blending these two disciplines.

The researches of Dr. Weed upon the cerebrospinal fluid now reach back 25 years. During that time he, along with a group of able coworkers, has unraveled an important series of fundamental problems regarding this intricate system, concerning which little was known when his investigations were starting. Under his guidance we have seen, as the readers of the Carnegie Year Books will know, the histology and embryology of the meninges clarified. This was followed by the demonstration of the sources of the cerebrospinal fluid and the pathways of its return to the venous system. There then followed the series of experiments which showed that the absorption of cerebrospinal fluid is the product of two factors, a hydrostatic one being the difference between the subarachnoid pressure and intracranial venous pressure, and the other the colloid osmotic pressure of the blood. This promptly led to the revelations regarding the pressure relationships between the cerebrospinal fluid and that in the cerebral veins, under the principle of the bony wall of the cranial cavity and the vertebral canal serving as a rigid container. There was then found the provision of elasticity which permits a dislocation of fluid on change in position by means of compensating dilatation and contraction of the intradural vascular bed, the cerebral venous pressure at the same time remaining constant. Associated with the latter experiments, a better hypothesis could be arrived at as to the primary function of the cerebrospinal fluid. It is owing to these researches of Dr. Weed that we now see it as a means of providing a prompt reciprocal volume and pressure adjustment when changes occur in the volume of the vascular bed or in the nervous tissue.

EFFECT OF INACTIVITY ON NUTRITION AND GROWTH OF MUSCLE AND BONE

The investigations of Dr. S. S. Tower on the isolation of the lumbar enlargement of the spinal cord in young growing animals has been extended to its trophic effect on the muscles and bones normally innervated from that source. In her experiments the cord was transected above and below the lumbo-sacral enlargement and all its posterior roots cut. When this is done the dependent muscles lose all ordinary activities including muscle tone. It was found that for purposes of these experiments young animals may survive several months and provide us with a method of studying the regressive changes which follow nerve section. Also in such experiments one can discriminate between effects of inactivation and those of nerve degeneration.

The three puppies used by Dr. Tower were studied 2, 5, and 6 months respectively. By the nature of her experiment all ingoing nerve impulses were excluded from the isolated cord, which nevertheless survived along with its dorsal root ganglia and peripheral nerves, without developing within itself any nervous activity. Since Dr. Tower had previously shown that severing of the posterior roots is without appreciable trophic influence on

skeletal muscle, any trophic disturbances resulting from these experiments would therefore have to be ascribed to the inactivation.

It was found that atrophy and metaplasia of muscle tissue into fibrous tissue, atrophy and destruction of subsarcolemmal nuclei, and interstitial fibrosis are all characteristic of inactivation of skeletal muscle. Macroscopically such muscles can be seen to be atrophied and they develop contractions. Microscopically the fibers are smaller in all dimensions, pale staining, and in the process of transformation into fibrous tissue, and the interstitial fibrous tissue is increased. The innervation remains largely intact.

All these things occur also in denervated muscle. But when a muscle is denervated it shows a rapid proliferation and change in character of the subsarcolemmal nuclei, which changes do not follow inactivation alone. This specific nuclear proliferation must be attributed to the degeneration of nervous tissue. Dr. Tower thus finds that the trophic control of muscle by the nervous system requires both physical integrity of innervation and nervous activation.

In analyzing the effects of inactivation on the postnatal growth of bone it was found that the long bones of the leg were normal in length and in their general configuration, features which appear to be intrinsic. In thickness and certain details, such as elevations at muscle attachments, they were underdeveloped. These then depend on extrinsic factors which in the above experiments were abnormal because of the presence of muscle inactivity. Special trophic nerves continue to be unnecessary to Dr. Tower for the discussion of the nature of trophic control of tissues.

ELECTROPHYSIOLOGY OF NERVES

It is only recently that any of our group have participated in investigations on the electrical properties of functioning nerve fibers. During the past year Dr. H. A. Howe in cooperation with Dr. D. A. Clark has made observations on fiber action potentials in the fiber tracts located entirely within the central nervous system. Observations on fiber action potentials had previously been restricted to peripheral nerves.

Dr. Howe and Dr. Clark studied the changes produced in the electrical potentials of the tracts within the cervical spinal cord following induction coil stimulation of the pyramidal tracts which lie on the ventral surface of the medulla oblongata, in the cat. They were able to demonstrate potentials somewhat analogous to those characteristic of peripheral nerves. The responses, however, were very complex and evidently included the activity of many fiber pathways. Owing to the structure of the cord it was not possible to determine the correlation between conduction velocity and threshold as has been done with peripheral nerves. Under the conditions of their experiments they obtained potentials which in form, rate of conduction, and resistance to asphyxia gave the picture of neuron fiber activity without synaptic intervention.

These investigators applied their stimuli to the pyramidal tracts by means of a bipolar electrode having two silver contacts set flush in the end of a bakelite rod. This rod was inserted tightly into a trephine hole through the base of the skull, in a manner that avoided blood loss or leakage of

cerebrospinal fluid. The resultant disturbances were registered by coaxial needle electrodes inserted into the cord at different distances from the point of stimulation. The two levels chosen were an upper one at the level of the second cervical vertebra and a lower one at the level of the fifth cervical vertebra.

Dr. S. S. Tower participated in a study of impulses as they pass through a sympathetic ganglion and into the nerves beyond it. She had the privilege of working with Dr. D. W. Bronk and his associates, who are experienced investigators in the field of electrophysiology of nerves. Their experiments consisted in stimulating the preganglionic fibers, rami to the stellate ganglion from the spinal cord, and recording the action potentials in the relatively long inferior cardiac nerve, to which the impulses were transmitted through the ganglion.

It was found that the conduction velocities in the nerve studied had a considerable range (1.4 to 0.6 meters per second), and there is a considerable temporal diversity in the maximum potential. Following the peak there is a positive after-potential which may be increased during the course of a tetanus. Likewise a negative after-potential develops after a tetanus. A rested nerve does not generally show a negative after-potential.

The significance of the action potential records which are yielded by the oscillograph is not altogether clear, and it is necessary at present to study them in all their details and under all possible experimental conditions. Among other things it was found by these investigators that a rapid series of preganglionic impulses initiates a single but dispersed series of postganglionic impulses. The records show that the individual nerve cell discharges but one impulse for each series. The dispersion appears to be due to differences in conduction time for the various fiber pathways through the ganglion. It was also found that the number of ganglion cells that respond to a preganglionic stimulus may be modified by various things. Arrest in the blood circulation decreases the number, whereas repeated stimuli can build up a larger response even in a non-circulated ganglion. Perfusion of a ganglion with drugs also modifies the nature of the responses. Although some of the terminology, the technique, and the character of the records are somewhat confusing to one who is not oriented in such matters, it is to be remembered that the workers in this field are collecting observations that lead to something more tangible as to the nature of the conduction of nerve impulses than the pure speculations which formerly were our sole resort. Some of the ground work in the electrophysiology of protoplasm was done with *Valonia*, that interesting primitive organism which abounds in the waters at the Tortugas Laboratory.

REGENERATION OF THE FACIAL NERVE AND ASSOCIATED TICS

In Year Book No. 35 a brief account was given of branched axones of the facial nerve in monkeys following experimental injury of that nerve. The results of those experiments have been published during the past year in final form in the *Archives of Neurology and Psychiatry* under the authorship of Dr. Howe, Dr. Tower, and the late Dr. A. B. Duel, who were aided by a grant from the Carnegie Corporation. These investigators have

established, both physiologically and anatomically, the fact that in regeneration of the facial nerve, following injury, its axones at that site undergo branching and subsequently innervate widely separate muscles and that in this way an irrevocable functional union takes place between muscles which do not normally contract simultaneously. There thus occurs a condition which resembles the ties which in humans follow injury of this nerve, and is characterized by an indiscriminate mass contraction whose proportion varies as the amount of damage to the nerve. These contractions show no tendency to regress, even over a three-year period. In man there is a better expectation of being able to suppress or modify the tic movements through reeducation.

IMITATIVE BEHAVIOR IN A MONKEY

A case of what appears to be imitative behavior in a young rhesus monkey has been studied by Dr. J. Ball. Being caged with a kitten for company, this 11-month-old animal learned to drink liquids by lapping, copying perfectly the technique of its companion. The new method of drinking continued several months, as long as the animal lived. The normal way of drinking and the one originally employed by this animal is a process of sucking. Among 600 rhesus monkeys whose habits have been closely followed in this laboratory, none have ever been observed to drink by lapping in this open-mouthed fashion. Dr. Ball concludes that this case can be interpreted as imitation.

BRAIN OF THE WHALE

Another contribution to the structure of the brain of the whale has been made by Dr. O. R. Langworthy in collaboration with Dr. F. A. Ries. Because of its many interesting adaptations to the requirements of marine life, Dr. Langworthy has made the whale brain the subject of several investigations, as the reader of these reports will know. The present investigation includes eight additional brains of the sperm whale, *Physeter catodon*, making Dr. Langworthy's collection, now housed in the Department of Neurology of the Johns Hopkins University, particularly adequate for such study.

DEFECTIVE BRAIN DEVELOPMENT

Dr. P. A. Fitz-Gerald of the Department of Anatomy, University College, Dublin, while a guest of our laboratory during the past year has made a study of the cerebral hemispheres of an eighth month child showing defective brain functioning. In the central and parietal regions the cortex of this child, instead of being properly fissured, was found to be almost smooth, and symmetrically so on the two sides. All the other cortical areas appeared to be normal. Dr. Fitz-Gerald associates the stunting of sulcus formation with a developmental arrest in cortical histogenesis and in this way he is helping to solve the problem which has long confronted the embryologist, of what is the exact nature of the forces that produce fissures and convolutions on the brain surface. He is following his surface survey of the material with a microscopic study of the tissues involved.

MORPHOLOGICAL STUDIES

CLAVICLES AND LONG BONES OF THE LIMBS IN MAN AND APES

In order to obtain suitable data bearing upon variability and asymmetries in higher primates and their comparison with man, Dr. A. H. Schultz has collected measurements and observations on a total of 753 human skeletons belonging to a variety of races, and a total of 530 simian skeletons belonging to all the genera of anthropoid apes and to macaques. The data have been obtained with the same technique and for the most part by himself and with the primary intention of its use for the study of variability and asymmetry. With it he has been able to make comparisons between some civilized and uncivilized races of man and comparisons between man and other primates, particularly the anthropoid apes. Heretofore we have had infinitely more data on asymmetries and variation in man than in other animals. Dr. Schultz has now provided the information regarding other related forms which we needed for evaluation of the data which were already available for man.

Among his observations on asymmetries he found, in comparing their distribution in man with that in apes and the macaque, that in general symmetry is rarer in the former than in the latter and that preference of asymmetries for one side is not nearly as marked in the apes as it is in man. In the macaque asymmetries favor both sides with practically the same frequency. In regard to asymmetries of the lower extremities man does not differ essentially from the other primates. In all primates there is comparatively little preference of one lower extremity over the other. Asymmetries in the lengths of the clavicles favor both sides with practically equal frequency in gorilla and chimpanzee and the right side slightly more frequently than the left in orang-utan, gibbon, and the macaque. This contrasts strikingly with the conditions in man, in whom there is a definite tendency for the left clavicles to be longer. In all the human groups the lengths of the long bones of the arm favor the right side in the great majority of cases, and the asymmetries of the arms favoring the right side are more frequent in females than in males among whites, Negroes, Eskimos, and Indians. Since Dr. Schultz had previously shown a similar prevalence of asymmetries in human fetuses, he concludes that the common preferential use of the right arm in man cannot be held responsible for its definite tendency to be longer. Nor is it likely connected with "right-handedness" since "left-handedness" is much rarer in man than are asymmetries favoring the left arms. Furthermore "left-handedness" is regarded as hereditary, whereas asymmetries of the human body are thought not to be.

In general the tables of Dr. Schultz demonstrate conclusively that man differs strikingly from apes and monkeys in regard to both the percentage distribution and the relative amount of asymmetries of the clavicles and the long bones of the arms; and that man and other primates are practically alike in regard to the degree of asymmetries and the difference in the preference of asymmetries for the two sides in the long bones of the legs.

VERTEBRÆ AND LENGTH OF SPINAL REGIONS IN PRIMATES

From observations made on 300 freshly killed catarrhine primates, with measurements made from the centers of the intervertebral disks, Dr. Schultz has been able to show that the cervical and the thoracic vertebræ are proportionately larger in all higher primates than in the lower catarrhines, and that among all primates man has the relatively longest cervical and thoracic regions and the comparatively largest lumbar vertebræ. However, the common evolutionary trend among higher primates to reduce the number of vertebræ and the relative length of the lumbar and caudal regions has gone to greater extremes in some anthropoid apes than in man.

In a series of 80 adult gibbons, having a much greater vertebral variability than man, it was found that a reduction in the number of thoraco-lumbar vertebræ is not accompanied by a corresponding reduction in the relative length of this region. On the other hand, a close correlation exists between decreased numbers of thoraco-lumbar vertebræ and increased numbers of sacral vertebræ. Less frequently the sacrum increases its number of vertebræ at the expense of the coccygeal region.

As compared with the lower catarrhines, man and the anthropoid apes differ not only in possessing fewer thoraco-lumbar and caudal vertebræ and more sacral vertebræ but also in having comparatively longer cervical, thoracic, and sacral regions and much shorter lumbar regions.

SHOULDER ARCHITECTURE

In previous reports reference has been made to the studies of Mr. Brazier Howell on the architecture of the shoulder in the vertebrate classes, including Amphibia and Reptilia. To these may now be added studies on the shoulder region of birds and therian Mammalia. In his description of the domestic fowl Mr. Howell has made a contribution to comparative anatomy by the interpretation of the avian shoulder in terms of the tetrapod animal. As in his other studies, due emphasis has been given to innervation in all questions of muscular homologies.

Among the noteworthy details pointed out by Mr. Howell are the following: the spinal accessory nerve and its associated muscles are absent, being replaced by a suboccipital group; m. levator scapulæ is lacking; the rhomboids occur in two layers; the subscapularis is poorly represented, whereas the dorsalis scapulæ and deltoid are robust; the large breast muscle represents the pectoralis minor element, the major being small and deep; supra- and infraspinati are absent; and the brachialis is a feeble muscle near the elbow.

In the anatomy of the appendages Mr. Howell finds a large break between those of the therian mammals and those of reptiles and even those of prototherians. In fact he finds that the monotremes are more comparable with reptiles than they are with therian mammals. For that reason he omits them from his analysis of the mammalian shoulder. He accounts for the great dissimilarity in the pectoral appendages of the above groups by the differences in the way the limbs are used. He points out the prone position of the reptilian body and the horizontal position of the humerus, with divergent

elbows, features which call for a very different skeletal and muscular provision from that with which we are familiar in mammals. The reptilian type of shoulder architecture is quite unsuited for quick movements and long-sustained action. In order to change the reptilian into the mammalian plan it was only necessary for reptiles to bring the elbow beneath the body. But this required such complicated skeletal and muscular adjustments about the shoulder joint that only a single reptilian group (Theriodontia) ever succeeded in its accomplishment. The improvement in function which resulted from the invention of the mammalian plan of shoulder seems to have played a large part in the development of the class Mammalia. The new deal provided the mammals with a means of using their limbs in a single plane, for purposes of locomotion, and over extended periods with the expenditure of much less energy. Over and above his interesting interpretations Mr. Howell's study has brought together a large amount of information regarding the shoulder region of mammals that will be of much value to the comparative anatomist.

MUSCLES OF HIP AND THIGH

The comparative anatomical studies which Mr. Brazier Howell has been making on the shoulder girdle have been supplemented by a similar method of analysis of architecture of the hip and thigh. His material includes the domestic fowl, the giant Japanese salamander, the reptile *Iguana*, and many varieties of mammals, a sufficient material for a comprehensive review of the homologies of the pelvic girdle.

It is pointed out by Mr. Howell that though the pelvic and pectoral girdles show many resemblances, yet the structures of neither pair can be properly homologized with those of the other, because of their difference in derivation. The cartilaginous pectoral girdle developed as an adjunct of the membranous girdle and is really a part of the head and axial skeleton. When the limbs became the primary organs of locomotion it was the pectoral limbs that propelled the animal by traction, and the girdle movement accompanying this action was accomplished largely by sidewise movements of the head. The membranous part of the girdle was derived from the posterior margin of the gill basket, whose musculature (trapezius) contributed to the control of the girdle. It had the complication of having a dual origin (membranous and cartilaginous) added to the fact of its location at the anterior termination of the axial musculature. With the pelvic girdle matters were quite different. The latter was initiated without the influence of anchorage to the axial skeleton, inasmuch as the pelvic appendages at first functioned for support only and not propulsion. For a long time they remained free of the axial skeleton, that is, from the viewpoint of the phylogenist. Furthermore the influence of the body muscles upon the pelvis were quite different from that upon the shoulder girdle. The story of the difference in functioning of the pectoral and pelvic limbs in the progress of their assumption of more complicated functions has been worked out in its significant details and Mr. Howell has provided the anatomist with a rationale for this region which is a definite advance over that heretofore available. With his four-group basis as the chief criterion, he has been able in large part to homologize the pelvic

muscles of urodeles, lacertilians, mammals, and birds. Even so there remain some specializations which still obscure their precise relationships.

VISCERAL ANATOMY OF AN INFANT CHIMPANZEE

An infant female chimpanzee, 74 days old, which died of an acute pulmonary infection, provided Dr. W. L. Straus, Jr., with an opportunity to study the thoracic and abdominal regions at this early stage. The body was injected with a 10 per cent formalin solution within one-half hour following death, giving excellent preservation of the tissues. Anatomical data on the viscera of this important primate are relatively scant and this appears to be the youngest infant thus far systematically studied. The sitting height and trunk height, measured after fixation, were 31.5 cm. and 16.8 cm., respectively. On comparing this specimen with an older chimpanzee and with an infant orang-utan Dr. Straus found that there are but small differences in visceral morphology between the two chimpanzee specimens though there is a difference of nearly four years in their age, whereas the contrasts between the infant chimpanzee and infant orang-utan are many and striking, an observation that will not surprise those who are genetically minded. Dr. Straus has made his detailed descriptions and measurements available to other investigators by formal publication.

BRANCHES OF THE AORTIC ARCH IN THE MONKEY

In Year Book No. 35 the investigations of Dr. C. F. De Garis on variations in the branches of the aortic arch in the macaque monkey were referred to and at that time the value of having a large number of specimens from a single species was pointed out. To his first series of 115 specimens, he has now been able to add 153 more. This provides a total series large enough for significant statistical treatment and for the consideration of problems of variation, inheritance, and symmetry. The new material when arranged in polygons of frequency further substantiates a norm having a short *truncus communis* comparable to that often found in man. This norm has a marked modal value which is intermediate between human and mammalian patterns, with almost equal distribution of these patterns on either side of the norm. The next step appears to be the search for correlations of this norm with trunk measurements and visceral structure and the consideration of the influences of body symmetry. This will inevitably lead the investigator back into the fetal period, where a large part of the determination of the vascular pattern takes place.

ASIATIC PRIMATE EXPEDITION

Joining forces with Professor H. J. Coolidge of Harvard University and Dr. R. C. Carpenter of Columbia University, Dr. A. H. Schultz participated in an expedition to northern Siam and British North Borneo in search of anthropoid material that is native there, and particularly the gibbon and orang-utan. Their program included comprehensive observations on the behavior and social relations of entire ape families as they live in their native jungles, and on the other hand the collection of skins, skeletons,

embryos, parasites, stomach contents, bodily measurements of the dead animals with a view toward species characters, growth before and after birth, variability, incidence of disease and injury, and any facts relating to pregnancy. Through careful preparations for the expedition and through the interest and assistance of the authorities of the countries which they visited they were able to obtain data and specimens for subsequent study at their home laboratories, in amount far beyond their expectations. From his own standpoint the large collection of gibbon specimens that has thus become available more than justifies the time and effort that Dr. Schultz devoted to the undertaking. The skeletons are now being cleaned and prepared for study.

PHYSIOLOGICAL OBSERVATIONS ON FIREFLIES

As a collateral to his cytological studies on insects Dr. J. B. Buck published during the past year his records on fireflies, an extensive collection of which were obtained by him on a visit to Jamaica in the preceding year while a fellow in the Zoological Laboratory of the Johns Hopkins University. In general he found that each species is rather definitely confined to a particular altitudinal range. A few species were found in a single district but most species are found in multiple regions where the altitude determines the appropriate temperature and moisture.

The observations by Dr. Buck on the spectral composition of the light emitted by the fireflies are of especial interest. Under the spectroscope the light emitted by all the species investigated produces a broad structureless band lying wholly within the visible spectrum. In no case was the light below 5050 or above 6550 Angstrom units. It is found that several species emit light of the same spectral composition, whereas others differ from one another. It is also noted that the spectra of some species present a relatively extensive range, e.g. 5050 to 6450 Angstrom units. Finally, Dr. Buck was able to demonstrate photographically that the apparently different color of the light emitted by the thoracic and abdominal light organs in certain species is due to an actual difference in the color and is not a subjective effect.

DEPARTMENT OF GENETICS ¹

A. F. BLAKESLEE, Director

CHROMOSOME INVESTIGATIONS

A. F. BLAKESLEE, A. G. AVERY, A. D. BERGNER, S. SATINA, H. E. WARMKE, J. T. BUCHHOLZ, J. L. CARTLEDGE, AND E. W. SINNOTT

Last year we reported the discovery, which had just been made, that treatment of seeds of *Datura* with the alkaloid colchicine would bring about changes in structure of the seedlings which were interpreted as due to doubling the number of their chromosomes. It was pointed out that if our interpretation were correct and the methods could be used with other forms, a tool of considerable value would be available both to the practical plant breeder and to the plant geneticist interested in problems of evolution. The present year's work has shown that induction of chromosome doubling by chemical treatment is of wide application among flowering plants and enables the investigator of certain problems to work with a measure of precision not hitherto possible. The polyploid series $1n$, $2n$, $3n$, and $4n$ have been secured in *Datura stramonium* and may be expected in other species. At the beginning of the calendar year Dr. H. E. Warmke joined our group and since then has assisted in the polyploidy investigations which have been supported by a grant from the Carnegie Corporation to the Carnegie Institution of Washington. The polyploidy project is a single phase of the chromosome problem which has been occupying our group. Other phases of this larger problem are not being neglected but it seems best to restrict the report this year to a discussion of progress in the polyploidy project.

METHODS OF INDUCING CHROMOSOME DOUBLING BY TREATMENT WITH COLCHICINE

Soaking seeds in solutions of colchicine of different concentrations for different species is the most convenient method of treatment. Seeds of *Portulaca* respond to a concentration of 0.0002 per cent for two days by producing seedlings with swollen stems. Seed treatment with 0.4 and 0.8 per cent solutions for 4 to 8 days has been found well adapted to *Datura* and induces an abundant production of $4n$ branches. The effect of the drug is first noted in delaying germination and development. When the treatment is severe the stems of the seedlings are strongly swollen and many fail to develop beyond the cotyledon stage. The leaves of affected plants are characteristically roughened owing to the fact that they contain a mixture of $2n$ and $4n$ cells. From these "mixochimeras" there ultimately may grow out branches with smooth leaves which either are normal $2n$ or contain twice the normal number of chromosomes and are therefore $4n$. The $4n$ flowers may be recognized by the larger size of their pollen grains or by the more tedious method of actually counting the chromosomes in young buds which have been fixed and stained by the acetocarmine method.

In addition to the seeds, vegetative parts of the plant may be treated by a variety of methods. The most successful method consists in spraying growing points with solutions or better with emulsions containing colchicine. To our surprise, injecting solutions and allowing solutions to be soaked up through the cut parts of the stem were not successful.

¹ Address: Cold Spring Harbor, Long Island, New York.

SPECIES IN WHICH CHROMOSOME DOUBLING HAS BEEN INDUCED

One of the early problems in the use of colchicine was the extent to which this drug would be effective in doubling the chromosome number of other forms than *Datura*. A number of species were selected for testing because of their adaptability to experimental cultivation or because of their relation to special problems involved in polyploidy. Following is a list of species of flowering plants in which at least flowers with doubled chromosome number have been secured through colchicine treatment.

PLANTS WITH CHROMOSOMES DOUBLED BY COLCHICINE TREATMENT

Those marked * have yielded $4n$ seed; those marked ** have given $4n$ offspring in second generation; unmarked plants were shown to have $4n$ tissue by flowers with 50 per cent or more $2n$ pollen grains.

CARYOPHYLLACEÆ

Lychnis dioica **

Stellaria media **

Vaccaria parviflora *

CHENOPODIACEÆ

Spinacia oleracea **

COMPOSITÆ

Bidens leucantha **

Cosmos sulphureus **

Rudbeckia hirta

CRUCIFERÆ

Raphanus sativa *

CUCURBITACEÆ

Cucurbita pepo

Mammoth pumpkin

Pear gourd

Small round china gourd *

"Spoon" gourd *

White sphere squash *

Yellow disk squash *

Straight-neck yellow squash *

Cucurbita maxima

Blue Hubbard squash *

Warren Essex squash *

Buttercup squash *

Cucurbita moschata

Small yellow cushaw squash *

Cucurbita maxima × *C. moschata* *

Lagenaria vulgaris

Dipper gourd

Giant bottle gourd *

Knobkerrie gourd *

Hercules Club gourd *

EUPHORBIACEÆ

Mercurialis annua

MALVACEÆ

Anoda lavateroides

MORACEÆ

Cannabis sativa **

Humulus japonicus

OXALIDACEÆ

Oxalis valdiviensis **

PLANTAGINACEÆ

Plantago lanceolata

POLEMONIACEÆ

Collomia coccinea *

Gilia abrothanifolia

PORTULACACEÆ

Portulaca grandiflora **

Portulaca marginata **

Portulaca oleracea **

Portulaca parana **

SOLANACEÆ

Datura ceratocaula **

Datura discolor

Datura ferox **

Datura innoxia

Datura leichhardtii **

Datura metel **

Datura meteloides

Datura pruinosa

Datura quercifolia *

Datura stramonium **

6 main lines and gene types *

8 races with extra chromosomal material *

Lycopersicum esculentum *

Nicotiana sanderae **

Nicotiana tabacum × *N. glutinosa* **

Nicotiana glutinosa × *N. sylvestris* *

Petunia axillaris **

VIOLACEÆ

Viola tricolor, *hortensis*

The 65 different kinds of plants shown in the list above have all been induced to double their chromosome numbers by treatment with colchicine. They represent 14 different families, 24 genera, and 41 species. Among them are 3 species hybrids.

The species successfully treated represent a considerable number of genera and families, enough to indicate that the method is of wide application. In addition, a number of forms which showed the vegetative peculiarities characteristic of tissue with doubled chromosome number following colchicine treatment were discarded for various reasons before the special treatment required to force out $4n$ branches had been developed. This was notably true of the grass family, but other investigators who have specialized on this family have recently been successful in securing $4n$ races of grasses through treatment with colchicine. The fungi seem highly resistant to the toxic action of colchicine. Miss Satina has treated a representative group of fungi with saturated solutions of colchicine (± 4.0 per cent) with no obvious effect. She has succeeded, however, in doubling the chromosome number of *Marchantia polymorpha* by treating the gemmæ with colchicine and has thus secured $2n$ male and female thalli of this liverwort.

POLYPLOIDY IN DATURA

Most intensive study has been made of the responses of the 10 herbaceous species of *Datura* to colchicine treatment. All appear to have their dividing chromosomes affected in such a way that cells with doubled and higher number of chromosomes result. *D. ceratocaula* is especially sensitive and is readily induced to double its chromosome number when treated by spraying with solutions of colchicine, a method not very effective with other *Daturas*. Certain races of *D. metel* appear to be somewhat resistant. Treatment of $4n$ seeds of *D. stramonium* has given rise to branches with $8n$ flowers, as has also severe treatment of $2n$ seeds. Such octoploid flowers have so far failed to produce seed. Hexaploid ($6n$) flowers have been secured by spraying growing points of $3n$ plants. A few large seeds from such $6n$ flowers have been formed but they have not yet been brought to germination.

Haploid ($1n$) plants appear not infrequently in our cultures through parthenogenesis of the reduced egg cells. Though some haploids produce very small capsules and an occasional seed, others are entirely sterile and cannot be induced to set any fruits. By spraying branches of a haploid with colchicine solutions it has been found possible to induce $1n$ cells in the buds to double their chromosomes and thus to become $2n$. An abundant production of large capsules with $2n$ seeds results. Methods are being investigated which it is hoped may be effective in inducing $1n$ offspring from $2n$ parents. If they prove successful, simple means would be available of producing homozygous races from highly heterozygous parents (such as species hybrids) through the induction of $1n$ seedlings which may be forced to produce normal $2n$ capsules through chromosome doubling.

Dr. Bergner has been making a study of the chromosomal condition in abnormal branches on plants from seeds treated with colchicine. Chromosomal deficiencies due apparently to elimination of lagging chromosomes during

the process of doubling appear to be common. Branches have been identified which lacked from one to six chromosomes but were otherwise $4n$. There is suggestion that periclinal chimeras may be present. These findings show that the immediate result of colchicine treatment cannot be depended upon to be balanced $4n$ tissue with four of each kind of chromosomes present. They furnish added justification for our rule that $4n$ plants for critical study should only be used from the second generation and not then until cytological study has demonstrated that each of the n sets has four chromosomes. Before another report we expect to have such pure $4n$ plants for all the 10 herbaceous *Daturas* as well as $3n$ individuals and these will be kept in cultivation by grafts and cuttings. Already we have gotten $4n$ flowers and seeds from 14 different lines of *Datura stramonium* which we wished to use as tetraploids for special purposes. Among these are a half-dozen pure breeders with extra chromosomal material which we wished to use in cooperative studies with Dr. Sinnott on anatomical effects of polyploidy.

DOUBLE DIPLOIDY

A well-established method of evolution both of cultivated plants and of plant species in nature is through the spontaneous doubling of the chromosome number of sterile hybrids between species. Such species hybrids are sterile because the chromosomes of the one parental species are too distantly related to those of the other species to allow the chromosomes to pair, and pairing is necessary for sexual reproduction. When the chromosomes in the hybrid are doubled in number the chromosomes of each species will find duplicates with which to pair and the hybrid will become fertile. It seemed desirable to see if such formation of new species could be induced by laboratory methods. Through the kindness of Dr. F. O. Holmes material was secured of the species hybrid *Nicotiana tabacum* \times *N. glutinosa*. This is completely sterile. By treating the hybrid plants with colchicine, fertile flowers have been induced which have produced an abundance of double diploid seed, and by the germination of the latter a double diploid race or new species has been established.

EFFECTS OF POLYPLOIDY

Now that a ready method of doubling chromosomes is available, it is possible to learn the effects of the doubled number upon the morphology and physiology of the plants affected. Conclusions regarding the effects of polyploidy have heretofore been too often drawn from polyploids found in nature in which the effects of polyploidy alone could not be easily separated from those due to genes which differed in the two members of the polyploid series compared. In consequence conclusions regarding polyploids have often been conflicting.

Since doubling chromosome number appears to have been a method of evolution in nature it is of importance to learn the effect of this process upon the sex mechanism in plants in which the sexes are separate. Evidence from related species in nature has been interpreted as signifying that doubling the chromosome number of a *dicocious* species gives rise to a hermaphroditic form. Other investigators believe that the chromosomal

mechanism would necessarily work against the establishing of either a hermaphroditic or a purely dioecious race by chromosome doubling. A study is being made of a series of dioecious species some of which are listed above as having had their chromosome number doubled. For such forms we should soon be able to learn the effect of polyploidy on the sex mechanism.

Another problem under investigation is the effect of polyploidy upon self-sterility, which is common among plants. A number of self-sterile species are being tested. In one case at least, preliminary tests seem to indicate that doubling the chromosome number neither increases nor decreases the degree of self-sterility.

In 1934 there were published by the Carnegie Institution the results of a cooperative study with Dr. Sinnott on the anatomy of extra chromosomal types in *Datura stramonium*. Differences in number and size of cells and in tissue pattern were demonstrated for $2n+1$ types and also for the balanced polyploid series, $1n$, $2n$, $3n$, and $4n$. It is still unclear how the qualitative differences are brought about between the members of the polyploid series. It is proposed to investigate this problem further than was possible in the preliminary study and to include a larger range of anatomical characters in all the herbaceous species of *Datura*. The possible antagonism between the influence of doubled chromosome number and the presence of unbalanced extra chromosomal material for which races are being developed by colchicine treatment will be investigated. It is thought that the qualitative effects of polyploids may be due to a differential effect of doubling upon different chromosomes. The effect of polyploidy upon size, shape, and growth rates can be better studied in some ways in fruits of the Cucurbitaceæ, a group in which Sinnott has carried on investigations for many years and in which highly inbred lines are available. As shown in the list above, the chromosome number has been doubled in a considerable number of Sinnott's squashes and gourds, so that tetraploids of these races should be ready for detailed study by next season.

ATTEMPTS TO DOUBLE CHROMOSOME NUMBER IN ANIMALS BY COLCHICINE TREATMENT

In cooperation with Dr. G. C. Embury and with the assistance of A. M. Phillips, attempts were made by the use of colchicine to induce tetraploidy in trout by treatment of eggs with the hope that the fusion nucleus could be induced to double its chromosomes before the first division. In cooperation with Dr. G. K. Noble and with the assistance of J. A. Mathewson, eggs also of frogs (*Rana pipiens* and *R. sylvatica*) and eggs of a number of aquarium fishes were treated with colchicine. In all these experiments difficulties were encountered in getting the drug to penetrate the membranes and in consequence the attempts to induce tetraploids in these animals were unsuccessful. It is possible that eggs which develop outside the body are better protected against unfavorable environmental influences than those which develop within the body. In consequence the latter might be more promising material in which to attempt chromosome doubling despite the technical difficulties involved in handling eggs of such species.

TESTS WITH OTHER CHEMICALS

By the use of *Portulaca* seedlings which show swellings of the stem due to tetraploidy when the seeds are treated with colchicine, a series of experiments were started in cooperation with Dr. Roger Adams to determine if possible what specific groupings of the colchicine molecule are necessary for the action of this chemical in doubling chromosome number. The following results were obtained with chemicals supplied by Dr. Adams:

Colchiceine—no effect

Trimethylcolchicinic acid hydrochloride—no effect

N-Acetyliodocolchinol—no effect

N-Acetylcolchinol—no effect

Benzoyl colchiceine—no effect

Colchicine salicylate—same reaction as colchicine

It is concluded that probably any modification of the colchicine molecule, even minor in character, causes the disappearance of its activity in doubling the number of chromosomes.

An attempt has been made to find other chemicals which would double chromosome number. A few have been found to react positively to the *Portulaca* test and to induce doubling in some of the cells, but none are as effective as colchicine. Sodium cacodylate, for example, induces a positive reaction with *Portulaca* and has induced $4n$ flowers in this species, but it is ineffective with *Datura*.

Work is under way on other problems which have to do with control of genetic behavior and with a better understanding of the nature and effects of polyploidy, especially as it relates to evolution in nature, but an account of these experiments is deferred to next year's report.

THE GENE

M. DEMEREC, B. P. KAUFMANN, AND MARGARET E. HOOVER

THE NATURE OF X-RAY INDUCED CHANGES

During the past year a cooperative study by H. Bauer, M. Demerec, and B. P. Kaufmann on chromosomal alterations induced by X-rays in *Drosophila melanogaster* was completed and the data were analyzed. The work consisted of an analysis of salivary gland chromosomes of first generation larvæ obtained by mating untreated females with X-rayed males. The chromosome rearrangements which were studied in this experiment were those induced in the treated sperm and not eliminated during the embryonic and early larval development, since glands were selected for cytological study from larvæ preparing to pupate. Experiments to be described later show that the death rate in these early stages of the life cycle is high. It is probable that non-viable chromosomal combinations are responsible to a large extent for that high death rate. In cytological analysis of salivary gland chromosomes we are dealing, therefore, with the surviving members of a much larger population. Permanent preparations of 1765 pairs of salivary glands were used and a total of 1038 chromosome breaks were analyzed. The X-ray radiation was applied by a Universal Type Coolidge tube, with

a tungsten target, at 85 kilovolts and 7 milliamperes, the dosage being measured by a Fricke-Glasser dosimeter.

The relation between the dosage and the frequency of breaks is shown in the accompanying table.

Dosage r-units	Sperm			Breaks per	
	Total	Number with alterations	Per cent with alterations	Total sperm (per cent)	Changed sperm (per cent)
1000.....	331	12	3.63 ± 1.03	8.16 ± 0.02	2.25 ± 0.13
2000.....	277	24	8.66 ± 1.69	22.02 ± 0.05	2.54 ± 0.18
3000.....	725	193	26.62 ± 1.64	72.00 ± 0.05	2.70 ± 0.09
4000.....	215	64	29.8 ± 3.12	85.58 ± 0.11	2.88 ± 0.18
5000.....	217	87	40.09 ± 3.33	125.35 ± 0.12	3.13 ± 0.16

It is clear from these data that there is no simple relationship between dosage and percentage of breaks per total sperm (fig. 1). The effect observed here is not directly proportional to the dosage, and this relationship is different from that observed in the case of lethal changes where the effect was found to be proportional to dosage. In this case the observed curve at low dosages (1000 and 2000 r-units) fits closely an exponential square curve, while at high dosages the deviation from it is appreciable. For its whole length the observed curve approximates an exponential 1.5 power curve which is intermediate between the first power of dosage curve and the square power curve. A similar relationship has recently been reported by Sax for chromosomal aberrations in *Tradescantia* and by Muller for genetically detected aberrations in *Drosophila*. Direct proportionality to dosage indicates that individual changes are induced by single ionizations, while a square power relationship would be expected, at least at dosage levels in which there is a low number of breaks per nucleus, if an individual change, in this case a chromosomal rearrangement, were caused by two independent ionizations.

Two types of regions can be distinguished in salivary gland chromosomes as well as in mitotic chromosomes of *D. melanogaster*, namely, euchromatic regions and heterochromatic regions. Heterochromatic segments are located in each chromosome near the spindle fiber attachment point and in salivary gland nuclei they come together into what is known as the chromocenter. In proportion to the total length, heterochromatic regions are appreciably longer in metaphase chromosomes than in salivary gland chromosomes. The study of 1038 breaks showed that they are distributed at random throughout the euchromatic regions, with the possible exception of distal sections, where breaks tend to be slightly more frequent. On the other hand, in heterochromatic regions of salivary chromosomes breaks were found to be much more frequent than in euchromatic regions of similar lengths. However, the frequency of breaks is found to be approximately proportional to the length of heterochromatic region as represented in metaphase chromosomes. This finding was discussed in last year's report (Year Book No. 36) and used as evidence to support the hypothesis that breaks are distributed

at random per unit length of chromonema, that the chromonema is structurally similar in all chromosomes, and that it may be looked upon as composed of fundamental units or backbones corresponding to the fiber protein molecule pictured by W. T. Astbury. The study of breaks showed also that they are distributed at random among chromosomes of comparable lengths. The analysis of two break cases indicates that these breaks are independent of each other, suggesting that a different mechanism is re-

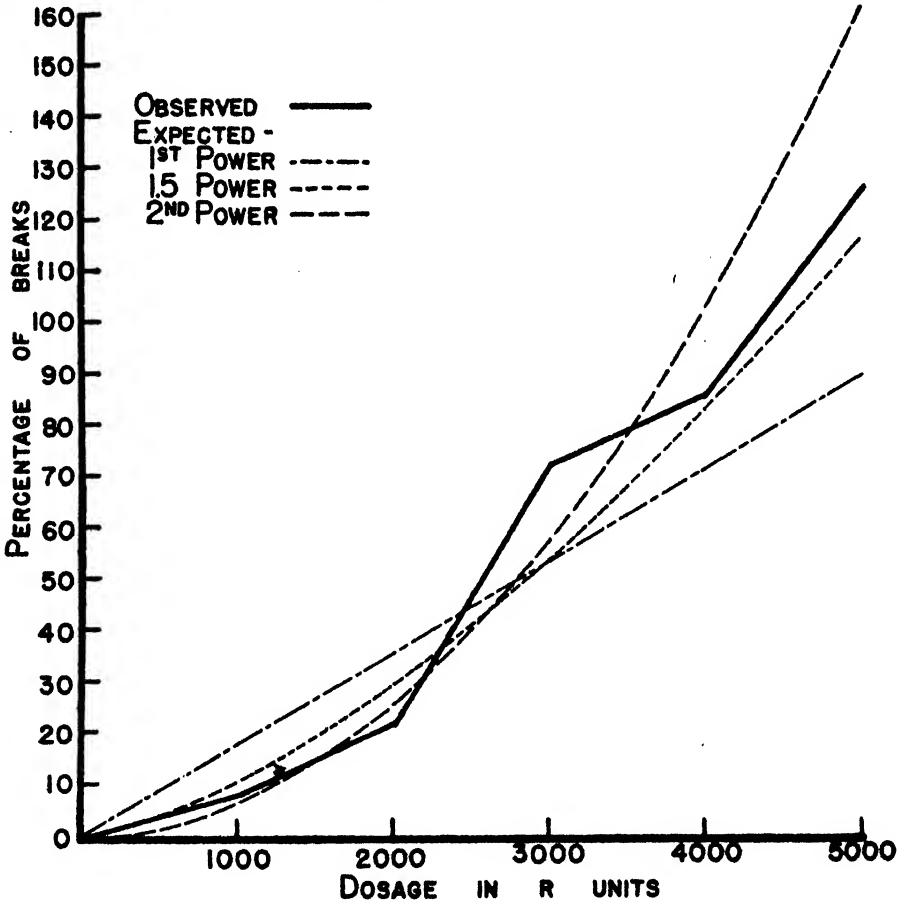


Fig. 1. Percentage of induced chromosome breaks in the total sperm. Curves show observed and theoretical values at different dosages.

sponsible for reattachments producing induced inversions and translocations than for those connected with crossing-over, where it is known that the position of the second break is influenced by the position of the first break.

The origin of induced chromosomal rearrangements may be accounted for by either of two mechanisms, namely, that a break in the chromosome occurs first and reattachment is accomplished later (Stadler), or that breakage and reunion are part of one process and occur simultaneously (Serebrovsky). The latter hypothesis assumes all regions involved in rearrangements to be

in contact at the time the reunions occur. In order to account for the rearrangements observed in our experiment it would be necessary to assume that in almost 20 per cent of cases more than two chromosome threads were in contact at one point, and to explain some of the complex rearrangements it would be necessary to assume that as many as six or eight threads were in contact at one point. The improbability of this condition combined with our analysis of the relationship between dosage and the percentage of breaks suggests strongly that X-ray induced chromosomal rearrangements result from such a breakage and reattachment mechanism as Stadler has proposed.

The cytogenetic analysis of the white-facet region of *D. melanogaster* was continued this year by Demerec and Hoover. A contribution to this study was previously made by Helen Slizynska (Year Book No. 36). With an X-ray treatment of approximately 2500 r-units, 81 separate changes have been induced so far in this region of the X-chromosome. Of these, 54 have been completely analyzed both cytologically and genetically at the time this report is made. These changes may be placed in three groupings, according to their genetic effect, namely, (1) changes that are viable, (2) changes that are lethal in the homozygous or hemizygous condition, and (3) changes resulting in a mottled phenotype.

The viable changes, owing to the method of detection, are all connected with the white locus. Out of a total of 25 such mutant whites, none was found to be connected with a major chromosomal aberration such as a translocation or inversion. Eight of these were studied for the presence of all critical bands and no deficiencies were detected in any. This finding indicates that at least the majority of viable changes are free from chromosomal aberrations and are not associated with minute deficiencies.

In the second group 28 lethal changes have been analyzed; 7 of these were found to be connected with chromosome changes and 21 were free from any rearrangement. This proportion suggests that a majority of lethal changes induced by this treatment are not associated with chromosomal aberrations and, consequently, must originate independently of the chromosome breaks resulting in inversions and translocations. These 21 lethals were subjected to careful salivary gland chromosome analysis. In 2 cases no known bands were absent, but 19 were found to be cytologically detectable deficiencies. Five of the 7 lethals associated with chromosomal rearrangements have been studied so far; 3 are not deficiencies and 2 are deficiencies.

The changes producing a mottled phenotype form a separate class. The 23 such changes collected so far have all been associated with chromosomal rearrangements. Of these, 13 have been studied for deficiencies and in only one case was such a deficiency detectable.

These results suggest that the majority of viable changes in the white locus are free from association with chromosomal aberrations and are also probably not gene deficiencies; that a high proportion of lethal changes are also free from chromosomal aberrations, but the great majority of these are cytologically detectable deficiencies. On the other hand, of those lethals connected with rearrangements, the minority may be deficiencies. The difference in this proportion may possibly be accounted for by position effect. All mottleds so far obtained are associated with chromosomal changes and

a great proportion of these are not deficiencies. All the chromosomal aberrations studied in relation to mottling have involved chromocentral regions. The chromocenters of all the chromosomes seem effective in somehow producing these mosaics. Three cases where rearrangements involving chromocenters have been detected have not shown this spotting, suggesting either that all portions of the chromocentral regions are not equally effective, or that some sort of differential position effect is involved.

It is interesting to note that the size of the deficiencies in this collection cover a fairly large range from single up to 46 bands. In the size range from 12 to 46 bands, the distribution seems at random, whereas there is a piling up of deficiencies of 1 to 4 bands. Out of 23 deficiencies analyzed, 13 were small, 5 of these being single bands. The other 10 were scattered over the larger size range. The study on distribution of breaks in chromosomes reported above shows that chromosome breaks occur at random and that they are independent of each other. Therefore, if deficiencies are caused by two independent breaks and loss of a piece between them, it would be expected that various sizes would occur with equal frequency. The data collected so far indicate that this holds true for deficiencies involving 12 or more bands but that it does not hold true for small deficiencies involving 1 to 4 bands. This suggests that these two classes of deficiencies were differently induced, large deficiencies by two independent changes or ionizations and small deficiencies by a single ionization.

RESPONSE OF HEREDITARY MATERIAL TO X-RAY TREATMENT

In last year's report (Year Book No. 36) data were presented showing that lethal changes induced in males by simultaneous treatments with X-rays were consistently almost twice as frequent in flies of the Swedish-b stock as in flies of the Oregon-R stock. It has been concluded that a biological factor was responsible for this difference in the effect of X-rays on the hereditary material. To investigate this problem further, another set of experiments was conducted in which the frequency of dominant lethals was studied. Males of Swedish-b and Oregon-R stocks were simultaneously treated with 1000, 2000, 3000, 4000, and 5000 r-units. They were mated to untreated females and the frequency of dominant lethals was found by determining the death rate during ontogeny. It has been observed that the frequency of dominant lethals is higher in the treated Oregon-R series than in the simultaneously treated Swedish-b series. In the case of dominant lethals, therefore, the behavior of these two stocks is just opposite to the behavior observed for sex linked lethals. This can be accounted for by either of the following hypotheses: (1) Dominant and recessive lethals are basically similar changes differing mainly in the degree of effect. The Oregon-R stock, when compared with the Swedish-b stock, is physiologically more sensitive to changes induced by X-ray treatment, and because of that sensitivity a greater proportion of individuals carrying these changes die early in ontogeny, the stock, therefore, showing a higher rate of dominant lethals and a lower rate of recessive lethals. (2) Dominant lethals and recessive lethals are, as far as the mechanism of origin is concerned, two unrelated types of changes; dominant lethals, for example, may be nonviable chromosomal aber-

rations while recessive lethals may be mutant types. Then the difference in the behavior of the two stocks may be accounted for by the presence of some biological factor which makes one stock more sensitive to one type of changes and the other stock more sensitive to the other type. In that case, two factors may be responsible for the increased sensitivity. It may be that, owing to a specific genetic constitution, chromosomes are more susceptible to breakages and genes to changes. A parallel case is on record regarding spontaneous mutations which were increased by the presence of a certain gene (Year Book No. 35). Or it may well be that this sensitivity is nothing else but an expression of a physiological condition determining the survival rate of various changes. In that case, the higher sensitivity of the Swedish-b stock to lethal changes would mean that owing to a physiological state certain changes which would be semi-lethal in Oregon-R stock are completely lethal in Swedish-b.

In the Oregon-R stock a 1000 r-unit treatment induced about 22 per cent of dominant lethals, a 3000 r treatment induced 63 per cent, and a 5000 r treatment, 78 per cent. This shows that a very large proportion of induced changes are being eliminated as dominant lethals. Since many of these are undoubtedly connected with chromosomal aberrations, this evidence indicates that probably a large proportion of these aberrations were eliminated before the stage at which the material was taken for the salivary gland chromosome study described earlier in this report.

CYTOLOGICAL ANALYSIS OF INDUCED CHROMOSOMAL CHANGES

An analysis of the numerous salivary glands of male and female larval descendants of irradiated fathers used in the study of break frequency and distribution has permitted diagnosis of various types of chromosomal alterations. These include deficiencies, duplications, inversions, inter- and intra-chromosomal translocations, and complex rearrangements involving two or more chromosomes. As many as 13 breaks per treated sperm have been detected. In one rearrangement involving 10 breaks, 2 bound an inverted section; the other 8 are included in a mutual exchange. About 1 per cent of the rearrangements contained duplicated sections, indicating that the chromosomes of the sperm were longitudinally double at the time of recombination of broken sections. One of these duplications, described by Kaufmann and Bate, is intercalary in the left limb of the third chromosome, and is arranged in the pattern of a "reversed repeat," as may be indicated by the sequence *abcdgfeefghijk*. Origin of the duplicated section is attributed to fusion of sister chromatids at the same level, thus: *abcd|efg|hijk* giving *abcdgfeefghijk*
abcd|efg|hijk

and probably another strand of the constitution *abcdhijk*, whose fate remains conjectural. Union of sister chromatids in the manner here indicated offers a possible explanation of the origin in nature of such reversed repeats as occur in the chromosomes of *Drosophila*. In another duplication Kaufmann found that both chromatids of the right limb of the second chromosome had been broken at one level but that a third break occurred at different levels in each of the two strands. Although it cannot be determined with certainty from this case that the second chromosome was split at the time

of irradiation, the rearrangement suggests the possibility that two strands may be broken at the same level by the secondary effects of a single ionization.

A considerable number of alterations showed transfer of the nucleolus from its normal chromocentral position to euchromatic regions of various chromosomes. From the pairing configurations in the salivary glands of individuals heterozygous for such exchanges it could be determined that the nucleolus-forming regions exist in the heterochromatic regions of the X- and Y-chromosomes, as had previously been described for mitotic chromosomes. In the X-chromosome the nucleolus is found between the 20B1-2 and 20C1-2 bands.

A cytogenetic study of nine inversions in the X-chromosome was completed by Margaret E. Hoover. These inversions, differing in size and position, were studied with particular attention to their cytological limits as determined in the salivary gland chromosomes. The inversions selected included four already familiar to *Drosophila* workers, namely, C1B, AM, dl-49 and Dichæte. In addition, an X-ray induced transposition (303-1) was used, three induced inversions associated with the cut locus, and the tandem inversion (268-13) mentioned in last year's report. Crossing-over data showed, as expected, that single crossovers are eliminated within inverted regions and greatly reduced in adjacent sections. Data on the amount of synapsis undergone in the salivary gland chromosomes carrying inversions indicate that even with these configurations a high degree of pairing is maintained. Even at the breakage points complete synapsis was observed very frequently. Based on 100 random observations, the lowest value for total synapsis through the inversion point was 48 per cent, the highest, 82 per cent. Disregarding lack of pairing for less than 1 to 1 section at these inversion points, the general aspect of the whole chromosome showed complete synapsis in 67 to 86 per cent of cases as compared with 90 per cent for controls. The relatively high frequency of synapsis in chromosomes carrying inversions is thus indicated, suggesting that synapsis occurs in the early stages of salivary gland development, when the thinner chromosomes would encounter less difficulties than the mature chromosomes in forming the inversion loops. The breakage points of the inversions were determined cytologically by salivary gland chromosome analysis. In all, 20 breakage points were studied. At 5 of these breakages, deficiencies were detected, at 13 no deficiencies were visible, and a single band at each of the other 2 remains unanalyzed. Those inversions in which the deficiencies were detected are also associated with lethals, but 303-1, a semi-lethal, and Dichæte and C1B, both lethal when homozygous, appear to be free from deficiencies. This would indicate that genetic-physiological lethals and cytological deficiencies are not necessarily synonymous.

In order to determine the nature of chromosomal alterations in cell generations immediately following radiation, J. G. Carlson, a guest investigator, treated embryos of the grasshopper, *Chortophaga viridifasciata*, and studied the mitoses in neuroblast and ganglion cells. Chromosomes which were treated in stages between telophase and mid-prophase show, in succeeding phases of the same mitotic cycle, chromosome fragmentation and translocation, chromatid breakage and translocation, and what may be half-chromatid effects. The presence of chromatin bridges at anaphase appears to result

from any of three different alterations: (1) chromosome translocation, (2) chromatid translocation, (3) fusion of sister chromatids of the proximal portions of fragmented chromosomes at their broken ends. The formation of such bridges and the persistence of broken ends from one generation to the next through breakage in late anaphase makes possible delayed attachments following irradiation.

The mitotic behavior of some fragments lacking spindle attachments parallels that of unaltered chromosomes in several respects. Such fragments lie in the equatorial plane at metaphase. Their "chromatids" begin to separate at anaphase at almost the same time as do those of the unaltered chromosomes, and they come into intimate contact with the spindle at middle anaphase. Sister "chromatid" fragments usually move toward opposite poles behind the other chromosomes, and so are included at telophase in different daughter cells. The initial separation of "chromatids" of fragments has the form of V's, rings, and pairs of rods. A hypothesis, based on the assumption that broken ends of sister chromatids tend to fuse *inter se*, is suggested to account for this. Not infrequently fragments are included at telophase in the newly formed cell nucleus. This behavior has a bearing on certain hypotheses of the mechanism of mitosis and on the question of delayed attachments.

EXPERIMENTAL LEUKEMIA

E. C. MACDOWELL, J. S. POTTER, M. N. RICHTER, J. VICTOR, M. BOVARNICK, M. J. TAYLOR,
E. N. WARD, T. LAANES, AND M. P. WINTERSTEINER

The cooperation of the College of Physicians and Surgeons of Columbia University with the Department of Genetics, which has made possible the establishment and continued progress of the leukemia project, has been broadened this year by the active participation of the Department of Biochemistry as well as the Department of Pathology.

Students of cancer have found that procedures that induce resistance to transplanted tumors of various types have failed to influence spontaneous tumors and they have largely abandoned the search for methods of inducing resistance to spontaneous tumors as a result of the current belief that the unique relationship between an animal and its own tumor cells makes the induction of resistance to these cells impossible. But this belief has been contradicted in the case of mouse leukemia (Year Book No. 35, p. 52) by the demonstration that parallel results are due not to the unique relationship between a mouse and its own leukemic cells but to immunological differences between leukemic cells in spontaneous cases and those carried through long series of transfers from mouse to mouse. Different cells require different conditions for survival or suppression.

From this point one procedure would be to search directly by the method of trial and error for conditions that would suppress spontaneous leukemic cells; another procedure would be to determine (1) the nature of the mechanisms of the successfully induced resistance to the long-transplanted cells, and (2) the basis of the change in leukemic cells during the course of transfer. With this knowledge it would be possible to proceed intelligently to build up conditions to suppress spontaneous leukemic cells. The first or

direct approach has been followed unfruitfully by numberless workers; the second or indirect approach represents direct contribution to the major aim of the Institution workers of this group, namely, an understanding of normal life processes as revealed by comparison with their abnormal functioning. Indeed the nature of the evolution of leukemic cells of the spontaneous type into the types found in the various transfer lines stands out as a primary problem both for its own broad significance and as a lead to the nature of the antecedent change of normal cells into spontaneous leukemic cells.

PASSIVE TRANSFER OF IMMUNITY

Certain transplantable tumors are said to induce resistance to themselves. Similarly for several years we have been consistently producing resistance to lethal doses of transplanted leukemic cells by means of sublethal doses of the same cells (Year Book No. 34, p. 45). This year the generality of this phenomenon has been broadened by experiments with still another line of leukemic cells. Such immunity seems to parallel that obtained by antigens and antibodies of conventional immunology, but the very general failure to obtain passive transfer of any tumor-induced immunity has made the identification of antibodies impossible, and leaves a question as to the nature of this induced resistance. During the year actively induced resistance to leukemic cells has been passively transferred to susceptible mice with success in 246 cases in 18 independent experiments with controls, in every experiment, on the lethality of the dose of leukemic cells in the absence of treatment. As in the studies on tumors, serum was ineffective; but immediate protection was afforded by the use of saline suspensions of minced tissue from actively immunized mice. The immediacy of the protection was emphasized by its effectiveness even when the immune tissue was given one to three hours *after* the lethal dose of leukemic cells. This is probably the first time that any type of induced resistance has completely suppressed a neoplastic growth transplanted *before* the protecting treatment was given. These results do not prove that an antibody, as usually understood, is concerned, since living cells are present. The protection, however, is not due to the living cells as such, for genetically identical living cells from non-immunized* mice give no protection. Passive immunization is usually demonstrated by cell-free extracts. In this case the demonstration depends upon the elimination of any form of active resistance by the immediacy of the protection.

The passive transfer of immunity provides a short cut in the technique of active immunization, as well as a new test for the development of active immunity. The process of actively immunizing a large number of mice has required many weeks and the initial steps have given uncertain results on account of the difficulty of controlling dilutions as great as 10^{-6} of the standard dose. The actual number of cells from the same suspension given to different mice may vary to the extent of killing some while others may not be given enough cells to induce any active resistance, and therefore die from the next higher dose. In such critical thresholds slight variations in the condition of the leukemic cells or of the hosts may have deciding influence. All these difficulties are avoided by starting with one treatment with im-

immune tissue. The usual lethal test dose ($1/64$ of the standard dose) is at once resisted by all mice and rapidly repeated massive doses build up the strength of the active immunity.

The process of building up active immunity has been studied by successive tests for passive transfer. After each step, tissue was transferred to still other hosts, which were then given the lethal test dose of leukemic cells. Tissue from a mouse treated only with immune tissue gives no protection; after the first leukemic dose, the tissue will protect some of the test mice; after two leukemic doses, the tissues will protect most of the test mice; while after three doses, the tissue will protect practically all the test mice. The production at a given date of any given number of mice actively immunized by leukemic cells is no longer a difficulty.

A CHEMICAL APPROACH

A possible lead for a chemical analysis and a clue to the difficulty of obtaining non-cellular substances that resist neoplastic growth have been found in the amazing ease with which the effectiveness of this supposed substance can be destroyed mechanically. The method is simply to force the saline suspension of minced tissue out of a syringe held firmly against the bottom of the vessel. This process almost immediately reduces all discrete bits of the tissue (liver) and in a very few minutes all cells are torn to pieces. Is the protecting substance denatured by the same pressures that destroy the cells, or is it so closely associated with cell structure (possibly as a modification of some normal cell constituent) that cell destruction is responsible for the inactivation? When injected into a mouse the cells of minced immune tissue are destroyed, but the effectiveness of the protection that accompanies them may persist for at least two weeks.

The importance of a chemical approach to questions raised by this project has been repeatedly emphasized. The recent advances in organic chemistry have disclosed such elaborate organizations of protein molecules as to approach the assumed complex "organization" of living matter. The chemist can no longer hold aloof from phenomena depending upon "organized" matter. A specific substance may be associated with living matter in the form of independent molecules operating as units; again, a special configuration may have no special effectiveness until it becomes established as an organic part of a normal molecule; or again, still more intimately, a special function may arise from the reorganization of molecular structures already present. Such considerations bear on several problems: on the nature of the change from normal to malignant; on the chemical differences between strains of mice genetically susceptible or resistant to certain transplanted leukemic cells; on the materials responsible for induced resistance, whether occurring naturally or put there by the host in combating growth of leukemic cells.

A significant broadening of the scope of the project has been made possible by the addition to this group of Dr. M. Bovarnick, working in the Department of Bio-chemistry under Dr. Hans Clark at the College of Physicians and Surgeons. During the year, Dr. Bovarnick has been approaching the problem of the mechanism of the resistance to transplanted leukemia that is induced by normal tissue. Normal growth-controlling mate-

rials are eliminated because the effect is specific for a given genetic differential between the constitution of the host and of the normal tissue used in the treatment. If antigenic action is concerned, it is unprecedentedly rapid (2 days) and calls for the startling assumption of antigenic similarity between a substance that appears only in highly virulent leukemic cells from one strain of mice and a substance found in all tissues of a certain other strain *without leukemia*. That some new protective principle should be involved seems entirely possible.

With the three biological variables—susceptible host, leukemic cells, and protecting normal tissue—controlled to the point of giving virtually 100 per cent results, a chemical analysis appears possible. The first step, however, has proved very difficult. Conventional chemical analysis requires separation from the vital organization of the cell; but all familiar procedures known to eliminate living cells have rendered the residues of the normal tissue ineffective. The pressure technique reported above has not been tested on normal tissue.

Previously the normal tissue used was embryonic, and this type of protection has been designated embryo treatment, but this year, adult tissues of the same strain have been found to be equally effective and, being far more available, have been used regularly. By using the same organ (liver) as for the passive transfer of immunity induced by leukemic cells, close comparisons can be made between liver tissue that protects by virtue of its genetic constitution, and liver tissue that protects by virtue of a non-genetic change induced by leukemic cells. In spite of clear differences in the resistance developed by these two different livers, the existence of the essential substance in each case is closely bound up with living cells. Another substance is also intimately bound up with living cells—that responsible for the malignant behavior of leukemic cells. To determine the relationship to living cells in any one of these three cases would serve as an important lead in the study of the others.

SPECIFICITY OF INDUCING STIMULUS

Since the interpretation of phenomena occurring before our eyes has been a leading policy, interest has been focused on the mechanism by which the leukemic process, once initiated, is maintained, and upon the extrinsic factors that are in fact active in the production of leukemia in our colony, rather than upon a search for chemicals that might experimentally induce this malignant growth. However, the study of the genetic factors involved in the observed incidence of spontaneous leukemia would be greatly aided by a chemical treatment that would reveal genetic potentialities at an early age. With this purpose, a study of the effect of a highly potent carcinogenic agent, benzpyrene, was undertaken in cooperation with Drs. C. J. Lynch and A. Claude of the Rockefeller Institute for Medical Research. In a strain of mice inheriting a high susceptibility to leukemia would this chemical hasten the appearance of leukemia? The evidence gives no indication of any such hastening in the appearance of leukemia, but benzpyrene does stimulate the occurrence of sarcoma as it does in other strains of mice. While other investigators have reported leukemia as the main result of

another chemical treatment, methylcholanthrene, the strain of animals employed did not otherwise show leukemia. The genetic constitution does not merely render certain tissue liable to become malignant, but determines susceptibility of certain tissues to certain agents. A genetic constitution that renders primitive reticular cells susceptible to certain stimuli occurring in our colony leads to leukemia; these cells are not susceptible to the action of benzpyrene; another genetic constitution might make these cells susceptible to the carcinogenic action of benzpyrene, and not to the stimuli responsible for the spontaneous leukemia in our strain C58.

The developmental hypothesis of malignancy reported last year by Dr. Potter has continued productively to guide thought and has been applied to a new series of phenomena. According to this hypothesis malignancy modifies the rate of normal cellular differentiation. This stands in contrast to the view that malignancy depends upon the creation of a new, uncontrollable cell type that reproduces only itself.

Variation in malignancy, according to the new interpretation, changes the rate of cell differentiation so that one or another stage preponderates, but, according to observation, all stages are present and each stage apparently divides at its own normal and characteristic rate. This includes advanced stages no longer able to divide, which accordingly can no longer contribute to progressive growth and so are no longer malignant. The continuation of a leukemic population depends on the presence of incompletely differentiated cells.

LYMPHOID VS. MYELOID LEUKEMIA

This hypothesis may now be broadened to cover the direction as well as the rate of development. Under the usual conditions of transfer from mouse to mouse the malignant factor in a given line has led differentiation consistently in the lymphoid direction for many years and through hundreds of normal hosts. But in hosts made incompletely resistant by normal tissue treatment, the direction of development may change and populations appear of leukemic cells in early stages of the myeloid series which terminates in polymorphonuclear leukocytes. Such myeloid populations when transplanted into untreated hosts may immediately develop into lymphoid leukemia with all the specific characteristics shown before. The hypothesis does not imply that early myeloid types have changed their course of development and become lymphoid, but that malignant control has been temporarily modified and, on return to a normal host, again directs the undifferentiated dividing cells in the lymphoid direction, while the myeloid cells are soon left behind by the new growth. In other cases more lasting change in the malignant control is shown by the continued production of myeloid cells in the following transfer or transfers. The outstanding instance of lasting modification showed a gradual return to lymphoid leukemia in the course of numerous transfers. In the tissue lesions of the hosts myeloid leukemic cells were found in the first four transfers and not thereafter; in the peripheral blood they persisted for thirty-four transfers.

Quite apart from the hypothesis regarding malignancy, the facts bring myeloid and lymphoid leukemia very close together; an unbroken continuum

of malignancy yields first one then the other type with return, abruptly or gradually, to the first type. This gives direct support to the theory of a common ancestral cell in normal animals, able to differentiate in either direction according to the needs of the individual.

In man, lymphatic, myeloid, and "mixed" types of leukemia are known, and even within the same case history changes in type have been recorded. But the genetic relationship between the various types has remained unsolved by clinical evidence. If the continuum responsible for malignancy controls both the rate of development and its direction, this continuum is subject to modification by the conditions of its environment. This environment in turn is subject to experimental and clinical control.

MALIGNANT LYMPHOCYTES IN TISSUE CULTURE

Through the cooperation of W. H. and M. R. Lewis and the Department of Embryology, living leukemic cells in tissue culture have been studied. Cultures were made of three lines of transplantable leukemia and observations were made microscopically and with the aid of a motion picture camera. At the conclusion of the observations on the living cells the cultures were fixed and stained for further study and reference.

These studies on living cells confirm the conclusion, derived from earlier studies with preserved material, that the malignant lymphocyte has the same morphological characteristics as a normal lymphocyte of the same stage of differentiation, and add the further observation that, according to the Lewis criteria, the method of locomotion of the leukemic lymphocytes studied is the same as that of normal cells.

Differences in transmission lines were evident during the early periods of the cultures; the most virulent line showed the largest number of blastic cells moving out from the explant. The high mortality of lymphocytes after the first day made further observations of little value. Roller tube cultures kept for 7 and 9 days had very few demonstrable lymphocytes although polymorphonuclear leukocytes were plentiful among the active fibroblastic growth. The malignant nature of leukemic lymphocytes makes their culture in artificial media no less difficult than that of normal lymphatic cells.

ENDOCRINE STUDIES

O. RIDDLE, R. W. BATES, J. P. SCHOOLEY, E. L. LAHR, G. C. SMITH,
R. A. MILLER, AND L. H. ELWELL

The regulatory powers of the anterior pituitary gland are now actively studied in many laboratories throughout the world, and in this field of study viewpoints may change markedly within a year. It has become clear that the pituitary gland largely provides for the regulation, adjustment, and coordination of the endocrine system, and for certain other activities of body and mind besides. Fitting this generalization into the broader and basic problem of organismal control and regulation, it would now seem possible to conclude that in higher animals and man the brain and the pituitary gland are the two prime sources from which the abilities of an individual are derived.

The investigations reported here, like those of past years, present parts of an effort to learn those endocrine agencies and mechanisms which condition or control functions such as growth (development), reproduction, and regulation in the bodies of higher animals and man. Much of the experience of the year points to the unpredictability of relationships among hormones; and perhaps the most notable thing observed is the extent to which one hormone may either increase (synergize) or decrease the specific action of another. These studies of Dr. Riddle and his associates have been greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

THE PREPARATION AND ASSAY OF PITUITARY HORMONES

We have now confirmed the report of others that the pituitary product, or products (adrenotropin), which increases adrenal size in rats is not prolactin. Our own preparations of adrenotropin, though containing only insignificant amounts of other hormones, are apparently crude fractions. During the past year all pituitary fractions obtained in connection with our preparation of pituitary hormones have been assayed not only on young pigeons but also on young rats. As a result of these routine assays on rats Bates and Riddle have obtained further evidence that most of our prolactin preparations are essentially free from adrenotropin, follicle-stimulating (FSH), and luteinizing (LH) hormones.

Of notable value to the general task of purifying anterior pituitary hormones is the demonstration of the usefulness of copper hydroxide for freeing one or more pituitary hormones from troublesome amounts of prolactin. After demonstration that $\text{Cu}(\text{OH})_2$ precipitates prolactin quantitatively from aqueous media at pH 6-7, this procedure was used to remove residual prolactin from two FSH fractions, one of which was derived from cattle pituitaries and the other from pig pituitaries. In neither of the resulting final preparations was there enough prolactin present in 1.0 mg. of product to provide a response with the local crop-sac test, showing that there remained in these FSH preparations less than 1 part of prolactin to 10,000 parts of the purified substance. Early results further indicate that a separation of thyrotropin from FSH may be accomplished by this same method.

Last year Dr. White of Yale University reported the preparation of prolactin in crystalline form, the first of the anterior pituitary hormones to be obtained in this state. Twenty milligrams of this crystalline prolactin, kindly supplied by Dr. White for our examination, was found to contain about 6.5 Riddle-Bates units per milligram. Some of our own more recent (noncrystalline) prolactin preparations have been found to contain as much as 10 such units per milligram.

Much work involved in the technique of assays has been performed by Mr. E. L. Lahr and Mr. L. H. Elwell. Mr. Graham Erdwurm has assisted in general laboratory work and has shared especially in the numerous assays made on rats.

FACTORS AFFECTING THE RESPONSE TO PROLACTIN

Since experience is proving that the quantitative response of the crop-sacs of doves and pigeons is modified by a number of factors (see earlier reports), it is necessary to identify and measure all such factors. Folley and White recently reported that antecedent and simultaneous high dosage with the ovarian hormone, dihydroestrone, markedly reduces the extent to which prolactin normally increases the crop-sac weight. This finding has been confirmed by Riddle and Bates, who obtain this diminished response with purified prolactin, and also with prolactin admixed with all other anterior pituitary hormones; but in the latter case the decrease is markedly less than in the former. Still other items of information concerning this restrictive factor were obtained which do not lend themselves to brief description here.

Folley and White also pointed out that their data, obtained with subcutaneous injection of ovarian hormone and prolactin, show the existence of a distinct sex difference (quantitative) of crop-sac response. Using intramuscular injections almost exclusively we had never observed a significant sex difference. Repeating the Folley and White experiments, and using the subcutaneous route of injection, the sex difference they describe has also been fully confirmed. In six different series (10 or more pigeons each) we found the male crop-sac weights indicated 1.5 to 4 times larger dosage than that indicated by the crop-sac weights of females.

RELATIONS OF PITUITARY TO SIZE OF BODY AND VISCERA

Observations reported last year concerning the effects of pituitary removal, and of the ability of various pituitary fractions (hormones) to sustain or promote general and localized growth, have been both confirmed and extended. Very little will be noted here concerning this line of study, which has been continued by Drs. Schooley, Riddle, and Bates.

When an unfractionated extract of the anterior pituitary gland is subjected to the action of trypsin it has been found to lose apparently all its power to repair the various disabilities that follow pituitary removal. This result indicates that all the pituitary hormones which participate in maintaining the weights of the body and particular organs studied are of protein nature. Further observations of growth phenomena in organs and in the body as a whole put emphasis on the high efficiency of a mixture of hormones. In pituitaryless pigeons the growth of the body as a whole, and growth in at least several of its parts (intestine, liver, pancreas, crop-glands, adrenal, and gonads), is accelerated more by mixtures of hormones of the pituitary than by its purified hormones acting singly.

HORMONAL BASIS OF MATERNAL BEHAVIOR AND BROODINESS

Three years ago, and on the basis of 160 tests, we reported that virgin and adolescent male rats can be made "maternal" in behavior by injections of prolactin, and that other pituitary hormones probably fail to induce this response. A total of 1780 tests have now been made, and the later developments of this study conducted by Riddle and Lahr will be briefly sum-

marized here. The accompanying table lists the hormones or substances found to act positively in inducing maternal behavior in rats of four classes—females, castrate females, males, castrate males. Another list of hormones has been found either to have no similar action or actually to inhibit maternal behavior; of these latter only a word need be said.

"Maternal" behavior induced in young rats by hormones

(The values given represent percentage of rats responding positively)

Sex	Control reactors	Prolactin	Pro-gesterone	Testo-sterone	Inter-medin	Whole A. P.	Phenol
Females.....	(28)	77	70	60	58	50	40
Spayed females....	(32)	79	78	83	.....	25	.....
Males.....	(23)	56	64	15	59	20	24
Castrated males....	(28)	75	61	53	56	43	57

It will be noted that intermedin, presumably produced in the intermediate lobe of the pituitary, induces this behavior; and extracts of the whole anterior pituitary (A. P.), containing prolactin and other hormones, are partially effective. One hormone secreted by the ovary (progesterone) and another by the testis (testosterone) are markedly effective, though apparently in lesser degree than is prolactin, while even carbolic acid seems effective in some cases. Though an adequate explanation of these results is not at hand there is some reason to suspect that progesterone and testosterone, as administered here, cause a diminished production of estrin, and perhaps also an increased release of prolactin from the rat's own pituitary. Conceivably this may apply also to intermedin and phenol, although evidence of depression of gonads by intermedin has been looked for and not found. It is fairly certain that depression of germ gland activity is one condition that favors the onset and exhibition of this parental behavior. Injections of highly potent gonadotropic hormone have repeatedly stopped, or diminished, maternal behavior after its natural occurrence ("reactors"), and also after its induction by prolactin or other hormone. Tests made with adrenotropin, cortin, parathormone, and thyroxine indicate that these hormones have little or no action on the maternal behavior of rats.

The colchicine technique has been used to determine whether the initiation of broody behavior in pigeons is or is not accompanied by a special or unusual release of prolactin from the bird's own pituitary, and thus whether an increased output of prolactin so coincides with the onset of broody behavior as to permit it to be causally related to it. The results show that this coincidence exists. At one day after the beginning of broodiness the preceding normal rate of mitosis in the crop epithelium has already increased by 600 per cent, and this higher rate is maintained and still further increased during the incubation cycle, near the end of which the secretion of crop milk begins. This result, involving a wholly new type of evidence, therefore definitely supports the conclusion that prolactin plays

a significant part in the cyclic development of broody and maternal behavior in higher animals.

Still other tests made by Riddle and Schooley relate importantly to this question of the mechanism through which the "broody instinct" arises in birds. They find that the corpus luteum hormone, progesterone, is capable of playing a part directly or indirectly in the initiation of broodiness in ring doves. Utilizing the "pellet implantation" method introduced by Parkes and Deansley, suitable tests were carried out—tests which avoid disturbances incident to repeated handling and injection of the birds. Implantation of such pellets of crystalline progesterone into adult and sub-adult ring doves, mated or unmated and of both sexes, is followed within 2 to 4 days by definite broody behavior. A pair of males thus treated carried out the incubation of eggs and the feeding of young. This ability to feed—the production of crop milk—demonstrates a release of extra or unusual amounts of prolactin prior to the end of incubation; but it has not yet been proved that in these particular cases (see above for pigeons) this release also occurs at or before the beginning of broodiness. Continuous dosage with progesterone was shown to be unnecessary, since birds completed the brooding cycle after the pellets were removed. It is also notable that immature doves do not react in this manner to this same treatment.

CYTOLOGY OF THE PITUITARY AND ADRENAL

An understanding of the structural basis of hormone production by anterior pituitary cells requires a correct interpretation of the life cycle of these cells, and no interpretation is susceptible of proof by direct observation. Nevertheless the subject is being studied with some success through indirect approach by Drs. Schooley and Riddle. Experimental modification of pituitary structure by treatment with hormonal and pharmacological agents, and by surgical procedures, have given some instances of nearly pure cultures of particular types of pituitary cells which can be correlated with known indices of physiological activity in the body of the animal.

In the pigeon's pituitary the undifferentiated cell (chromophobe) is interpreted as an embryonic element capable of maturing into either acidophil or basophil. These latter cells produce and release the hormones characteristic of the anterior pituitary and then die or undergo dedifferentiation into chromophobes. Indications were obtained of the manner in which the differentiated functional cells accomplish this dedifferentiation. The granulations seen in the pituitary cells seem not to be the active or actual hormone; and therefore the release of hormones does not rid the cell of the accumulation of granules present during active secretion. Apparently, however, such cells throw out this accumulation of granular material and are thus rejuvenated for a new cycle of activity. This discarded material accumulates between and outside the cells and becomes the pituitary "colloid" observed in the pituitaries of most animals. The rejuvenated cells have embryonic characteristics and appear to undergo further division, thereby producing a new supply of chromophobes which take up the work of hormone production as they mature into chromophils.

The adrenal cortex produces one or more hormones under the stimulus of one or more pituitary hormones. The cytological changes that occur in the adrenal glands following hypophysectomy, and following administration of various pituitary hormones to normal or hypophysectomized pigeons, have been studied during the past year. A rich supply of adrenal tissue from birds previously subjected to many types of treatment is obtained in connection with other current investigations, and Dr. Richard A. Miller has studied the cytological changes thus induced in the cortical cells. It has been found that in the normal bird these cells contain very little fat; that hypophysectomy is followed not only by the well-known decrease of cortical tissue but by a great accumulation of fat (up to more than half of the cell volumes) in the persisting cells; that this accumulation of fat is progressive during more than 10 days (probably during 20 or 30 days); that such accumulation of fat is prevented by administration of whole extracts of anterior pituitary and by pituitary fractions rich in adrenotropin; and that these two types of pituitary preparations, even in fasting hypophysectomized birds, tend to increase the mitochondria and to restore the Golgi apparatus to or toward the condition found in the normal unoperated bird.

PITUITARY HORMONES AND CARBOHYDRATE METABOLISM

Both uncertainty and confusion characterize current reports concerning the pituitary hormones which affect carbohydrate metabolism. Further studies on one aspect of this problem have been made by Dr. Riddle, in association with Dr. Louis B. Dotti of New York Medical College. Prolactin moderately but consistently increases the blood sugar in all types of pigeons, in doves, and in rabbits (New Zealand Whites). In these species prolactin acts upon the blood sugar in much the same way (though in somewhat less degree) as do extracts containing all the pituitary hormones. Adrenotropin also is found to have a somewhat similar action on blood sugar, and still other results provide evidence that at least two different pituitary products affect the metabolism of carbohydrates.

Following Collip's recent report on the glycemic action of intermedin in rats and dogs, a new interest attaches to the action of that hormone. A slight glycemic action of intermedin was observed in normal rabbits and pigeons, but even a slight action was absent in eight tests made on hypophysectomized pigeons treated for 5 to 8 days. Details connected with these studies indicate that it is not possible to ascribe to intermedin the effects on blood sugar and basal heat production of pigeons which we have assigned to prolactin. The prolactin crystals of White, even in the low dosage used, increased the blood sugar of hypophysectomized pigeons.

BASAL METABOLISM IN FUNCTIONAL REGULATION

It becomes increasingly important to know which pituitary hormones have an action on basal heat production. More than a year ago O'Donovan and Collip reported that the hormone usually known as intermedin also has power to raise the B. M. R. in rats. That result made it necessary to learn whether intermedin and prolactin have comparable effects on the

B. M. R. of pigeons. This and some related problems have been studied by Riddle and Smith during the present year.

Intermedin, prepared and assayed in Höchst, Germany, and obtained through the courtesy of the Winthrop Chemical Company, was injected daily (500–1000 Phoxinus units) for 3 to 10 days into groups of pigeons. Measurements (36) made on normal pigeons 6 hours after a last injection of the hormone gave slightly higher (4 to 7 per cent) values for the heat production; other measurements (10) on hypophysectomized pigeons gave values 2 per cent above their control. The insignificant differences observed seem to demonstrate that intermedin and prolactin do not have comparable effects on the B. M. R. of pigeons.

The action of small amounts of the crystalline prolactin of Dr. White was studied in small groups of hypophysectomized (4) and of normal (8) pigeons. The former group was studied after 3 daily injections of 3.3 units (0.5 mg.) and the B. M. R. was found to be increased by about 14 per cent; the normal pigeons received one-half the above noted dosage during 3 days and at that time showed basal values increased by 12 per cent.

The action of adrenotropin on heat production is being studied. Two groups of normal pigeons given heavy daily dosage (10 mg.) during 3 and 9 days, respectively, increased their heat production values by 9 per cent. Since 10 mg. of this preparation of adrenotropin contains nearly 1 unit of prolactin, and since we cannot now declare it to be entirely free from thyrotropin, these incomplete data indicate that adrenotropin has little or no effect upon the basal heat production of pigeons.

Useful but now little-understood results were obtained from a comparison of the basal metabolism of normal and hypophysectomized young (2-month) pigeons, when both types were continuously fasted during 10 days. Measurements made on small groups of these two types of pigeons gave the unexpected result that at 5, 7, and 9 days after removal of their pituitary glands, and at 6, 8, and 10 days of fasting, these pigeons have a higher metabolic rate (measured at 30° C.) than have unoperated birds similarly fasted. At the above-named periods the operated group produced only 9, 8, and 5 per cent less heat than when unoperated (and fasted for only 24 hours); but the unoperated group at these periods of advanced fasting, produced 19, 27, and 31 per cent less heat than when fasted for the standard period of 24 hours. Our study of heat production in these and other related conditions continues to assist an interpretation of the mechanism of pituitary action.

OTHER STUDIES AND ACTIVITIES

Last year Dr. Bates reported a rapid method for the determination of the tryptophane content of proteins. Further studies have shown that the intensity of color developed by that method can be increased about 10 per cent and the small but disturbing drift of intensity previously present can be eliminated. These desirable results were obtained by using a smaller amount of HCl (80 ml./100 ml. final volume), and by diluting to volume with 50 per cent ethanol instead of with water. With these improvements the method gives excellent and reproducible results.

Utilizing the recently introduced technique of McGinty and associates for demonstrating qualitatively the presence of extremely minute amounts of progesterone, Riddle and Schooley have tried to learn whether the corpus luteum hormone, progesterone, is produced in birds. Two types of bird ovaries were taken as possible sources and extracted according to the method of W. M. Allen (1932); in each case approximately 15 g. of fowl ovaries (yolk previously removed from follicles) were extracted. One sample of ovarian tissue was obtained from actively laying hens; the other sample, of similar fresh tissue, was from hens in various phases of egg production but previously injected (with prolan) daily for three days in an attempt to luteinize their ovaries. Neither of the resulting purified extracts contained enough (1 gamma) progesterone to produce a positive reaction in the prepared uterus of a suitable rabbit. The best available evidence on this point therefore indicates either that such fowl ovaries do not produce progesterone or that they produce an amount nearly or quite insignificant in comparison with that formed in the ovaries of adult mammals.

Studies initiated but not reported last year showed that a rapid hyperplasia of the crop-sac epithelium of pigeons quickly follows the injection of prolactin, and that this can be clearly and quantitatively measured by the colchicine technique. Details concerning quantities of colchicine (0.6 mg. per 500-g. bird) and time of injections of both the drug and the effective prolactin have been learned and published by Lahr and Riddle. This method was further used in the study of several related problems. In the crop-sacs of adult pigeons it was found that an injection of prolactin (60 units) is followed by (induced) cell divisions within less than 30 minutes; the maximum rate of mitosis occurs after 2 hours, and the effect is not observable after 10 to 12 hours. When a second injection of prolactin is given 8 hours after a first, this has produced a greatly enhanced effect 2 to 4 hours later. Mr. L. H. Elwell has assisted in the determination of the extent of this increase in mitotic rate following the administration of prolactin.

In a study made during a few months of summer, Riddle and Dotti have confirmed and extended their work reported last year on the calcium-raising properties of female sex hormones. Sufficiently high dosage has now been shown to be effective in castrate male rabbits; but very high daily dosage (3 mg.) of estrone to rats may be less effective than much lower dosage, and under no dosage hitherto used is the blood calcium of rats greatly increased. Recent results show that estrone is wholly incapable of increasing the serum calcium of parathyroidectomized rats. This result favors the view that the action of the sex hormones on the serum calcium is secondary to their action on the parathyroids.

Several theoretical considerations make it worth while to know which of the many compounds chemically related to the group of sex hormones is capable of causing growth in the uterus. And from a phylogenetic standpoint this same information has added interest when it pertains to the uterus (oviduct) of a bird. A current study of this problem is being made by Riddle and Lahr, to whom Dr. Erwin Schwenk of the Schering Corporation has supplied generous quantities of the crystalline compounds.

The quantitative effect of these substances evidently undergoes unexpected seasonal variations, and this fact precludes a satisfactory description of these results at this time. Dihydroestrone, estrone, progesterone, androstendiol, dehydroandrosterone, testosterone, androsterone, and pregnenolone have all proved effective (and in nearly this order) on the oviducts of ring doves injected daily (1.5 mg. or less) for 7 days; cholestenone was ineffective. The effect of estrone on the dove oviduct is markedly synergized by progesterone. Possible and interesting theoretical implications of this particular fact may be noted. Though progesterone seems not to be produced in birds (see above), their oviducts, like the uteri of mammals, are capable of reacting markedly to the presence of this hormone. This suggests that when evolving mammals produced progesterone for the very first time the chief tissue (oviduct, uterus) upon which the hormone acts was already sensitive to its presence. Thus it is unnecessary to postulate a coincident or concurrent origin of two genetically unrelated things—a new hormone and a new or special sensitivity of a particular tissue to that hormone.

STUDIES IN EUGENICS AND HEREDITY

HARRY H. LAUGHLIN

SURVEY OF THE HUMAN RESOURCES OF CONNECTICUT

Early in the year which ended June 30, 1938, the task allotted in the collection of data, both by first hand field work and by correspondence, was completed, and during the latter half of the year the main efforts of the Survey were expended in the analysis of the returns and in the preparation of the Survey's Report No. 1.

The following progress report reviews briefly several researches conducted by the Survey:

ANALYSIS OF THE LAWS OF CONNECTICUT IN DIRECT REFERENCE TO THE HUMAN RESOURCES OF THE STATE

(a) *The constitutional law of Connecticut* which defines and limits the function and authority of this sovereign state in its control of population by numbers, race, and inborn quality. This analysis of the legal background of the eugenical function and authority of the state covers the basic items of (1) definition, (2) population, (3) quality, (4) race, color, alienage, (5) migration control, and (6) the census and control of handicapped persons, in the main historical and legal documents which laid the governmental foundation of the present Commonwealth.

(b) *Statute-reference and abstract of the laws of Connecticut* which bear directly upon the eugenics of the Commonwealth, i.e., upon the establishment and maintenance of racial ideals and family-stock standards, upon the determination and maintenance of the optimum total population number and distribution, and specifically upon handling the inadequate and handicapped members of the population. This analysis covers the *General Statutes of Connecticut* in force on January 1, 1938; that is, the *General Statutes of Connecticut, Revision of 1930*, and the *Session Acts of 1931, 1933, 1935, and 1937*.

The present analysis of the statutes of Connecticut presents a new point of view in the study of state law. Its purposes are, first, to enable the student of human resources to locate immediately the statute reference with a short abstract of every law which bears upon any one of the several eugenical subjects listed. The second purpose is to bring together with special clarity, and organized in systematic manner, all laws of the state which bear upon the subject of eugenics or race improvement, and thereby to enable judgment of the completeness, orderliness, and adequacy of the statutes on this subject, with special facility in locating any gaps, contradictions, overemphasis, or repetitions which may exist therein. The third purpose is to indicate a possible codification of the laws of the state in reference to the conservation of its human resources.

THE 169 TOWNS OF CONNECTICUT, EACH IN RELATION TO ITS PROBLEM OF INADEQUATE AND HANDICAPPED RESIDENTS

The state of Connecticut is divided into eight counties. These eight counties, in turn, are composed of 169 towns in all. In Connecticut the county government is of little consequence compared with that of the state on the one hand and the town on the other. The real center of local government in Connecticut is the town.

The Survey of Human Resources assembled the basic geographic and demographic statistics of the 169 towns, and added to them the findings of its own first hand researches on the inadequate and handicapped residents of each town. These studies covered the census of inadequate and handicapped individuals resident of the town, the town's responsibility for such residents and how the town discharges such responsibility, and the classes and numbers of such residents who are cared for by the state custodial or residential institutions for the inadequate or handicapped classes.

THE PROBLEM OF THE FEEBLE-MINDED IN CONNECTICUT

This Survey has given a special consideration to the problem of the feeble-minded within the population of the state. Making critical use of the most accurate standards for the mental measurement and the diagnostic classification of the feeble-minded, the present Survey collected and analyzed the case histories of the 11,962 definitely feeble-minded residents of Connecticut. It is estimated that, using the same standards, a complete census of the mentally deficient in the state would have found the total number of such defectives equal to approximately 17,500, or practically 1 per cent of the entire population of the state.

These 11,962 feeble-minded persons—the total number who came under the purview of the Survey—have been studied individually in reference to nine subjects, as follows: (1) sex, (2) age, (3) recidivism, (4) diagnostic class, (5) intelligence quotient, (6) race descent, (7) nativity, (8) citizenship, (9) kin in institutions.

The present Survey has completed twenty-one tables of cross-classification by pairs of the above listed traits and qualities for selected group units and totals within this population.

CROSS-CLASSIFICATIONS OF TRAITS AND QUALITIES OF THE INMATES OF INSTITUTIONS AND OTHER SELECTED SOCIALLY INADEQUATE OR HANDICAPPED POPULATION GROUPS OF CONNECTICUT

In this section of the Survey of the Human Resources of Connecticut, 19 portfolios consisting of a total of 346 cross-classification tables have been worked out.

The purpose of this system of classification is to provide more definite facts in reference to the history, characteristics, qualities, and origins of the particular social class or population group which is under analysis. In the current researches particular attention has been paid to the cross-classification of such matters as, for example, race descent *against* intelligence quotient;

First Subject: INTELLIGENCE QUOTIENT and Class Limits or Types									
	26-50	51-70	71-80	81-90	91-110	111-125	UNKNOWN	TOTAL	
Second Subject: DIAGNOSTIC CLASS	CRIMES AGAINST CHASTITY	3 .290 .231	27 .227 .214	23 .193 .177	25 .210 .170	12 .101 .124		29 .244 .175	119 1.000 .180
	CRIMES AGAINST PERSONS	3 .012 .231	36 .133 .286	43 .165 .331	60 .231 .406	27 .104 .346		91 .380 .548	260 1.000 .303
	CRIMES AGAINST PROPERTY	7 .028 .536	96 .225 .444	59 .237 .454	55 .221 .374	35 .140 .440	1 .004 1.000	36 .148 .217	249 1.000 .377
	CRIMES AGAINST PUBLIC POLICY		7 .212 .096	5 .192 .038	7 .212 .048	4 .121 .091		10 .303 .060	33 1.000 .079
	TOTAL	13 .020 1.000	126 .191 1.000	130 .197 1.000	147 .222 1.000	78 .118 1.000	1 .001 1.000	166 .291 1.000	661 1.000 1.000

Fig. 1. Sample cross-classification, intelligence quotient against diagnostic class, for the 661 inmates of the Connecticut State Prison for Men at Wethersfield, September 1, 1937

race descent *against* diagnostic class; or kin in institutions *against* intelligence quotient.

A representative study of the social inadequates of the state. Besides the inmates of several other institutions, the inmates of the Connecticut State Prison for Men at Wethersfield were cross-classified by pairs of subjects among the above listed nine items. Selections from these cross-classifications give many direct questions and answers such as the following:

What is the comparative intelligence-distribution among those Connecticut men prisoners of Italian descent and those of American blood, for whom I. Q.'s have been computed?
Answer:

I. Q.	Prisoners of Italian descent (per cent)	Prisoners of American blood (per cent)
26-50.....	2.39	1.91
51-70.....	32.59	20.79
71-80.....	29.02	26.36
81-90.....	25.60	28.36
Above 90.....	10.40	22.68
Total.....	100.00	100.00

What is the distribution of intelligence among the 119 men committed to the Connecticut prison for crimes against chastity—the so-called sex crimes?

Answer:

I. Q.	Percentage of prisoners committed for sex crimes
26-50.....	2.5
51-70.....	22.7
71-80.....	19.3
81-90.....	21.0
Above 90.....	10.1
Unknown.....	24.4
Total.....	100.0

It is noted that the idiot class, I. Q. 0-25, is not represented among these prison inmates, and that for nearly one-fourth (24.4 per cent) the I. Q. is unknown.

THE DIRECT COST TO THE PEOPLE OF CONNECTICUT THROUGH EXPENDITURES BY THE STATE GOVERNMENT (EXCLUSIVE OF EXPENDITURES BY COUNTY AND TOWN GOVERNMENTS AND BY PRIVATE PHILANTHROPY AND CHARITY) FOR THE MAINTENANCE, CARE, TRAINING, AND TREATMENT OF THE DEFECTIVE, THE DEPENDENT, THE DELINQUENT, AND THE HANDICAPPED CLASSES

The Survey made a special analysis of the relative and absolute costs of the inadequate and handicapped population to the state government of Connecticut for the fiscal year 1935-1936 as compared with the fiscal year twenty years previous, 1915-1916.

While the money cost has mounted, the economic drag and the biological cost, as other items of the Survey have shown, have mounted still more rapidly, and the state is thus confronted with serious financial, economic, and biological problems, in the increasing numbers of inadequate and handicapped members of its population by reproduction and net migration, as compared with the competent and adequate members of the state's population and their relatively lower reproductive rates and net migration gains.

Change in twenty years (1915-1916 to 1935-1936), or in but little more than one-half of one human generation

	1915-1916	1935-1936	Per cent change
Estimated population.....	1,219,174	1,734,000	+ 42.23
State governmental expenditures for all purposes.....	\$7,339,428.00	\$47,436,626.94	+546.33
Such per capita expenditures for all purposes.....	\$6.02	\$27.36	+354.48
Total expenditures for defective, dependent, delinquent, and handicapped classes.....	\$1,503,022.00	\$11,479,544.66	+663.76
Portion of total state expenditures devoted to defective, dependent, delinquent, and handi- capped classes.....	20.5%	24.2%	+ 18.04
Per capita cost.....	\$1.23	\$6.62	+438.21

From these data such conclusions as the following may be drawn: (1) In 1937 the people of Connecticut were expending, through their state government (exclusive of county, town, municipal, and private expenditures),

more per capita for the maintenance, care, training, and treatment of their socially inadequate and individually handicapped classes than this state government was expending for all purposes twenty years ago. (2) At the present rate every inhabitant of Connecticut is expending, through his state government, five and one-third times as many dollars per year on the socially inadequate and the individually handicapped as the average inhabitant was spending for the same purpose twenty years ago.

EXPERIMENTAL CENSUS AND REGISTRY

One unit study in the Connecticut Survey of Human Resources is called "The Experimental Census and Population Registry of One Town." A representative town of about 2500 inhabitants was made the subject of this study, and field work was undertaken to make a census and registry of as large a portion of its population as available field workers would permit.

A card was designed and used as the basis of this experimental population enumeration and registry. The specific additions included such matters as personal identification by fingerprints, classification by race descent, and relationships to near blood-kin and to relatives by marriage. This card, which was used in the present experimental census registry, provides for records which show more definitely than the usual census the status and change of the subject-population in reference to race descent, tongue, literacy, medical case history, reproductive rate, occupation, employment, and economic condition, as well as family connections and conditions.

STUDIES IN HUMAN HEREDITY: ACTUARIAL GENETICS

During the year steady progress has been made on the analysis of stature inheritance in the American population, and concurrently in the development of the actuarial aspect of genetics. In the latter researches, the main question is: "When a given problem in human heredity is presented, accompanied by certain definite data concerning the possession or degree of development of the subject-trait among certain definite near-kin, by what probability will the pre-indicated offspring possess the named quality to the specified degree?" The subject-trait in its somatic development may be almost entirely hereditary; it may be almost entirely environmental; it may be a resultant of these two developmental forces acting in a definite combination; and the hereditary part may be based upon one Mendelian gene or upon a complex of many. In any case the actuarial probabilities are worked out by comparison of Nature's behavior in the antecedent distribution of the subject-trait within the subject-family as given with the same trait distribution among definite blood-kin within other families drawn from the same general population, all other factors being randomly represented.

CLINICAL SERVICE IN HUMAN HEREDITY

Up to the present time the Eugenics Record Office has not served, nor intended to serve, in the capacity of a clinic in human heredity, but in an increasing degree such possible service is being forced upon the attention of the

institution. Inquiries, either directly or by reference from other laboratories which were addressed directly, are sent to the Eugenics Record Office by intelligent members of families with specific problems in human heredity—physical, mental, or spiritual. They are sent also by physicians and friends of handicapped subjects, particularly by physicians who have not specialized in human genetics and who, therefore, call upon research students who have become expert in this field to collaborate with them.

In experimental response to these demands for clinical service in the field of human heredity, a new survey of the present status of knowledge of the rules of inheritance of given diagnosable and measurable human qualities has been undertaken, with the possibility of practical clinical service constantly in mind. The individual who applies to a clinic of this sort presents a definite problem in human heredity and desires an answer in the form of a definite "yes" or "no," or, at least, an answer in terms of dependable probabilities—as dependable for instance as the actuarial probabilities computed by a reliable insurance company in its own field.

GENETICS OF THE THOROUGHBRED HORSE

RACING SUCCESS OF LABORATORY-PRODUCED THOROUGHBREDS

For many years Walter J. Salmon of New York City, distinguished breeder and racer of the Thoroughbred horse, maintained in conjunction with the Carnegie Institution of Washington a laboratory for research on the measure and inheritance of racing capacity. The scientific work of this laboratory was conducted by the Eugenics Record Office at Cold Spring Harbor, Long Island. A part of this work consisted in assembling and analyzing racing records of individual horses and of groups of definitely related Thoroughbreds. The second part of the laboratory consisted in the breeding farm, which put to experimental test the findings and indications of the researches in the racing and pedigree analysis. This experimental breeding farm was maintained by Mr. Salmon as the Mereworth Stud, in Lexington, Kentucky.

This laboratory in the course of its experimental breeding for the production of high racing capacity produced two of the most successful racing Thoroughbreds of recent years. These horses are:

Discovery, by Display, out of Ariadne; date foaled, 1931

Flat racing capacity, 140.93; number of races run, 63; number of races won, 27; number of races in which the quality of performance was above 1.000, 16.

Battleship, by Man O' War, out of * Quarantine; date foaled, 1927

Flat racing capacity as a 2-, 3-, and 4-year-old, 123.48; number of flat races run, 22; number of flat races won, 10.

Won Grand National Steeplechase at Aintree, England, March 25, 1938. Time, 9:29 4/5; distance, 4 miles, 856 yards; number of competitors, 13.

RESEARCH PUBLICATIONS

In January 1938, the complete texts for the so-called "Black Book," which is the practical work-volume to accompany volume I on the *Measure of racing capacity*, and for the so-called "Brown Book," which is the practical work-volume to accompany volume II on the *Inheritance of racing capacity*,

were deposited with the Washington office for publication. These two books contain the formulæ and tables necessary for actual use (1) by the judge of racing capacity in the individual horse, and (2) by the practical breeder in planning mate selection for high racing capacity in the foal. The two basic volumes with their respective work books will complete the series of studies as originally planned on the genetics of the Thoroughbred horse. Volumes I and II will give the original data and their analyses which developed respectively the yardstick for the measure of racing capacity and the formula for predicting racing capacity in the foal. The experimental work has been finished, and the texts and figures for volumes I and II are in course of preparation for publication.

ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND MARY ELIZABETH GRANT

GROWTH IN CHILDREN OF DIFFERENT RACES

The work on the physical development of approximately 400 children belonging to the Negro, white, Navajo, and Maya races has continued throughout eight years. During that time, two height-weight-age tables were prepared, one for Navajos, the other dealing with Dutch whites in Michigan. With their publication, the need of intensive studies on homogeneous groups was stressed. Up to this time, our studies have concerned chiefly cross-sectional data. In this report, we are able for the first time to present some findings from our longitudinal material. The growth trends for males and females of the four races previously mentioned, based on average annual increments of stature, are shown in figure 1. These curves were made following a system described by Shuttleworth.¹ The mean stature at a base age involving the greatest number of available cases was selected (age eleven, in this study), the average annual increment between 11 and 12 years was added to this mean, and the 12- to 13-year increment added to the 12-year figure, etc. The average increment between 10 and 11 years was subtracted from the mean of 11 years, and that between 9 and 10 was subtracted from the 10-year figure, etc. This method has the advantage of greater reliability in indicating the pattern of growth than can be obtained by cross-sectional data. For each age and sex the number of individual increments ranged between 20 and 50.

From figure 1, it will be noticed that the Maya are approximately 10 cm. shorter for each age than the Navajos, who in turn are consistently shorter than the Dutch. The Negroes are taller than the Dutch for all ages up to 14, when the Dutch surpass them and remain taller into adulthood.

It is generally known that white boys are taller than girls from the ages of 6 to approximately 11, at which time the girls are taller than the boys until approximately 14 years, when the boys again lead in stature. From figure 1 it will be seen that this same general condition holds for all the races, except that for the lower years the points of the first decussation occur at different ages. Thus, for the Maya the point is at 9 years, for

¹ F. K. Shuttleworth, *Sexual maturation and physical growth of girls age six to nineteen*. Monographs Soc. for Research in Child Development, vol. 2, no. 5, pp. 217-219 (1937).

Navajos at 10 years, and the Dutch seem to have two points, one at 7.5 years and the other at 11, while for Negroes the point of decussation occurs at 9.5 years. It is of interest, however, to note that the second point of decussation, or that age at which the males again become taller than the females, is between 13 and 14 years for each race.

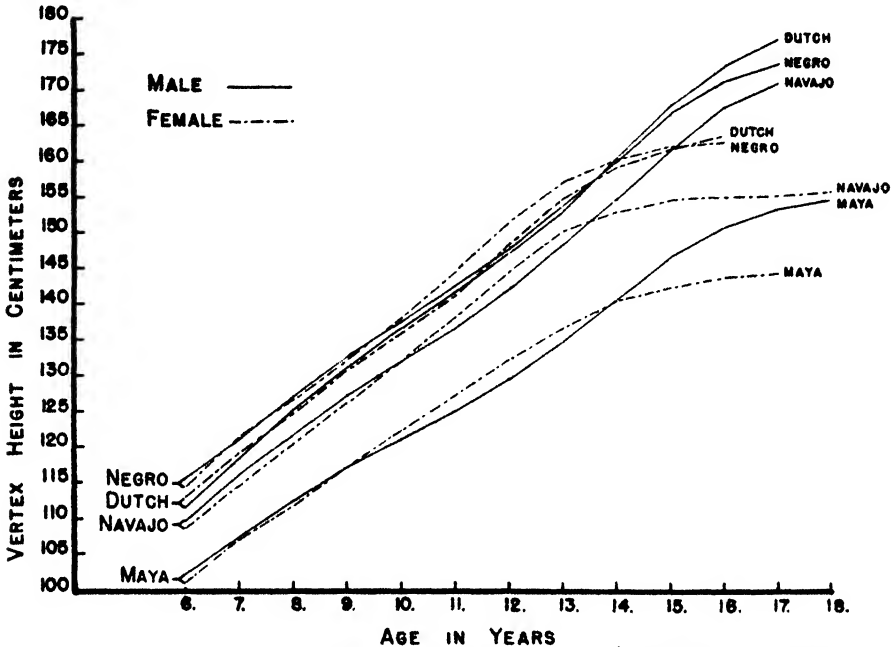


Fig. 1. Growth trends for males and females of four races based on average annual increments of stature

The growth trends in stature for males of these different races is curiously the same. The average annual increment decreases from 6.5 to 10.5 years of age for each race, at which time the rate increases until 14.5 years, after which the rate falls. This means that at 10.5 years there is a minimum of growth for each race considered, and at 14.5 years there is a maximum of growth for each of these races. After this age the rate of growth decreases rapidly for all races with the Navajos decreasing at a slightly slower rate than the others. This similarity of growth is of interest when one considers that these groups live in entirely different habitats. The Navajos, for example, live at an altitude of 6000 feet, while the Maya live practically at sea level and in a subtropical region. The Dutch whites live in the northern United States, while the Negroes live in Alabama. The food habits of these different races are likewise very different; for example, in the main, the Navajos are protein eaters living on mutton when they can, whereas the diet of the Maya consists of from 75 to 80 per cent maize products. The average annual increments for girls of these same races are not quite so definite, although they follow practically the same general growth trend. The Negro, Dutch, and Navajo girls reach their highest rate of growth between 11 and 12 years, after which the rate of growth decreases; the Dutch,

however, continue to grow at the same rate for another year. The Maya girls grow less at every age than do the other three races up to the age of 13 years, after which the Navajos and Negroes have lower increments.

The question was asked whether individuals who were short at an early age attained the average stature of the population, or whether they remained short throughout life. Twelve individual Maya boys were selected at random, all of whom were taller than the mean 11-year-old stature for the race. Likewise, 12 individuals, all of whom were shorter than the 11-year-old mean, were selected and their annual growth plotted. This same procedure was followed for 24 Maya girls. The curves for males show that the two groups remain relatively separate; that is, the tall 11-year-old boys were taller at every age for which we measured them, and the boys who were shorter than the average at 11 years were shorter for every other age. It will be noticed that the curves for the short boys begin to flatten out at 16 and 17 years, indicating that their growth is nearly completed. The curves for girls are practically the same except that at the older ages, 14 and 15 years, the short girls continue to grow, whereas the taller girls have stopped growing at those ages. These statements are preliminary and more data are being gathered for more conclusive evidence.

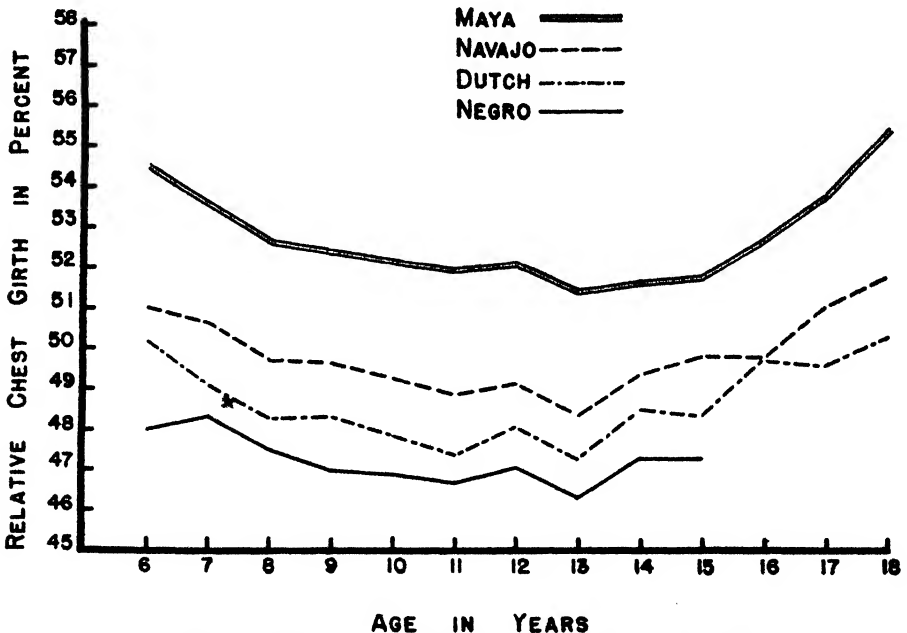


FIG. 2. Mean relative chest girth for male children of four races

Cross-sectional data show that the Maya children have relatively large chests when compared with Navajos, whites, and Negroes (see figure 2). Male children of each of these races have a lower relative chest girth at the ages of ten to fourteen than they do at six or eighteen years of age. That is, male children just previous to the adolescent spurt of growth for these four races are relatively slender. The Maya children are least slender; for

example, at thirteen years of age, the average chest girth for Maya boys is 51.4 per cent of their stature. For Navajo boys the ratio of these dimensions is 48.3 per cent. Dutch whites, who are still more slender, have a chest girth which is 47.3 per cent of their stature at thirteen years of age, while Negroes, who are most slender, have a relative chest girth of 46.3 per cent for this age. These differences are all statistically significant. The difference between the mean relative chest girth of the Maya and Navajo is 12 times the probable error of the difference. Between Navajo and Dutch, the difference equals 4 times the probable error, and between Dutch and Negroes, the difference is more than 3 times the probable error of the difference.

ETHNOBOTANY OF THE MAYA INDIANS

In a study of the medicinal usages of 25 plants used by the Maya of the Chichen Itza area, it was found that 11 of them have been used consistently by colonial and modern doctors and the Indian herb doctors, as well as by the lay Indians, for some specific ailment. It is of interest and perhaps of significance to note that these 11 plants are used widely and have been used specifically for nearly four hundred years. Thus, *Euphorbia hirta* L. and *Rauwolfia heterophylla* R. & S. have been used over this period for sore eyes and granulated lids, but their properties are so well known that even the *yerbateros* (herb doctors) go to considerable detail in warning the public not to use too much of these dangerous plant juices. For coughs and colds, *Mimosa hemiendyta* Rose & Robins. has been used over this entire period by educated doctors and uneducated Indians alike. *Jatropha Gaumeri* Greenm. has been used consistently for mouth sores, as well as for diarrhea and dysentery, which may indicate that the plant contains a drug which acts on the mucous membranes of the mouth and intestines.

If the number of times a disease is mentioned by independent sources for treatment indicates the prevalence of the disease, then diarrhea and dysentery, coughs and colds, fevers and chills, skin diseases, sores and ulcers, and kidney trouble and urinary disorders are most abundant, each having been cited twenty times or more. Everyone acquainted with the tropics knows that the above-mentioned diseases, with the possible exception of kidney trouble, are exceedingly common, and the incidence of these disorders as given by Shattuck² proves that this contention is true. Next in importance are hemorrhage, sore eyes, and snake bites. Tuberculosis is mentioned only once, unless blood vomit may be so considered. Confirming this, Shattuck states, "We saw in our clinics very few cases of pulmonary disease which were typical or even suggestive of tuberculosis." Malaria is mentioned only twice, but may have been considered under a heading of aches and pains, or another general group called fevers and chills, although the modern Maya readily distinguish between malaria and other fevers. Syphilis and gonorrhea are mentioned only by the colonial and contemporary doctors and never by *yerbateros*. This might bear out the findings of Shattuck, namely that the modern Maya are comparatively free from both of these diseases.

²G. C. Shattuck and collaborators, The Peninsula of Yucatan: Medical, biological, meteorological and sociological studies. Carnegie Inst. Wash. Pub. No. 431 (1933).

He says (page 257), "Clinical evidence of syphilis was found to be practically *nil*, alike in the Maya and in the Mestizos of our series." It may be that the colonial and contemporary doctors treated chiefly Spaniards for these diseases.

Eye trouble, including conjunctivitis and granulated lids, is listed rather often in the text material, and two plants (*Euphorbia hirta* L. and *Rauwolfia heterophylla* R. & S.) are consistently used for its specific treatment. The Maya are reputed to be relatively free from trachoma, although folliculosis is common among children. Toothache, pyorrhea and gum trouble, sore mouths, and fever sores seem to be relatively common. For toothache, one plant has been used consistently, namely *Krugiodendron ferreum* (Vahl) Urban. Snake bites have also been treated uniformly throughout the historic period of Yucatan by *Pisonia aculeata* L.

The purpose of this small study was to determine whether the modern usages of plants were the same as those in the seventeenth and eighteenth centuries. It was learned that this was true for 44 per cent of the 25 plants. During this time, from ten to fifteen generations have elapsed, and the information has been handed down chiefly by word of mouth. The modern *yerbateros* are illiterate and have not had access to any medical texts. Thus, it is suggested that there may be true medicinal properties in many of the plants considered.

In addition to these 25 plants, 175 were considered for all usages ascribed to them. Of these, 134, or 77 per cent, were used by the Maya as medicine for specific ailments. For all but a very few plants, more than one medicinal usage was given, and some plants had three or four medicinal usages ascribed to them. Samples of extracts of 36 plants used medicinally were purchased in the Merida drug store, showing a widespread use of plants for medicine among the Maya.

Seventy-three of these 175 plants are eaten as fruits and vegetables by the Maya, plus 33 others which are said to be food for their domestic or wild animals. Thus, 106, or 61 per cent, of the 175 plants serve as food. Some of these plants form the main sustenance of the Maya. For example, maize (*Zea mays* L.) supplies 75 per cent of their diet. The Indians depend greatly on honey produced from the nectar of certain trees.

Twelve per cent of the 175 plants are used for lumber and house construction purposes. In addition to these main usages, twenty-two other categories are listed which show the extensive use of plants by the Maya Indians.

TESTING THE PSYCHOLOGY OF RACES

In our last report we described a modification of the McAdory Art Test in which pictures of horses, cows, trees, clouds, and other natural objects replaced pictures of the dresses, fences, silverware, automobiles, etc., of the McAdory Art Test. Our modified test was given to Navajos and Dutch whites, with the interesting result that the Navajos judged all objects from a utilitarian standpoint, while the whites judged them more from the point of view of art. During the current year, the test was further revised in such a way as to eliminate the consideration of utility. For example, such objects as belts, hats, saddles, and boots were used instead of horses and

trees, etc. In this test, the subject was shown four belts or four hats which differed in artistic value, but were the same from a utilitarian standpoint. At the time of this writing, the results have not been analyzed.

Dr. Theodora Abel, a psychologist in New York City, has devised a test in which the subject is asked to draw a symmetrical design, using 19 straight lines and 6 curved lines. The author was asked to give the test to an adequate number of Dutch whites in Michigan and Navajos in Arizona, which were to serve as norms for her study on schizophrenics. Dr. Abel has completed her study, and writes as follows concerning the testing:

"Schizophrenics, whose predominant and prevailing attitude is a persecutory paranoid trend, perform in a characteristic manner when asked to make a design of limited scope. They are unable and unwilling to build up a constructive idea about arranging straight and curved lines in a pattern as do normal subjects, and are obsessive about following explicitly the instructions concerning the limitations of the task, namely employing a certain number of lines. They do what they are told as long as the task is one of simple understanding and recall (drawing 19 straight and 6 curved lines), but do not carry out the other part of the task which requires some use of thinking and imagination . . .

"We have indicated that more normal individuals, but those who have some characteristic paranoid trends, perform more like the patients than like normal people in making the design. We have pointed out also that a very maladjusted Navajo Indian, who was a gifted artist, made no attempt at making a pattern but drew the straight and curved lines linearly and rigidly as did the schizophrenics, whereas the other Navajos tested showed flexibility in working out definite patterns in their designs."

Dr. Margaret Curti of Columbia University and the author are cooperating in a study on young Maya children from Yucatan. The Minnesota Preschool tests were redesigned so as to be applicable to Maya children. Thus, in test 3, "Naming of familiar objects," instead of cups, balls, and watches, pencils and scissors, which were called for in the American test, the Maya children are asked to name an orange, a piece of henequen string, a stone, and a chili pepper. The test also calls for naming parts of the body, locating objects in pictures, vocabulary, etc. All testing was administered by Pedro Castillo, a Yucatan schoolmaster of about fifty years of age, a man who commands the respect of all school children. Some preliminary results of this work are summarized by Dr. Curti as follows:

"1. The 'Minnesota-Maya Tests' as now in use in Yucatan constitute useful material for testing 'intelligence' in young Maya children, for the following reasons: (a) Many of the tests, and the scale as a whole, show increasingly good performance with increase in age. (b) All of the children who attempt the tests are able to do something with them; and a wide range of ability is shown. (c) A child's attack on the tests is in general rather consistent—i.e., he can do several tests at his age level, indicating that in general the tests are adapted to the abilities of the children. This does not hold of all the tests; and a few of the items must be discarded as not fair to the Maya children. But there are enough good tests to constitute an adequate 'measure' of the children's ability.

"2. The children in general show good ability in the tests, on certain items tending even to excel American children who have been given the same tests. This suggests that when dealing with material familiar to them, the 'intelligence' of the Maya children is not inferior. This is a striking find and will be of great interest to students of psychology and anthropology.

"3. There are probably more shy or uncooperative children among the Maya group than commonly found in an American group of the same age. For unusually shy or uncooperative children the tests do not of course furnish estimates of intelligence. The same thing holds true of very shy or uncooperative American children.

"4. Some individual children do outstandingly good work on these tests. This suggests that the tests would be a useful means for helping to select superior individuals who might be sent to school or otherwise specially encouraged.

"5. The results so far are especially significant in that they demonstrate the possibility of using specially adapted tests for the comparative study of the intelligence of primitive and more advanced peoples. Test comparisons so far made have shown marked inferiority in test performance on the part of the more primitive of the two 'races' compared, but of late it has been increasingly recognized that the inferiority is probably related to such factors as unfamiliarity with the methods and materials, and shyness. In the present study special efforts have been made to eliminate such factors as far as possible."

NUTRITION LABORATORY¹

THORNE M. CARPENTER, ACTING DIRECTOR

The early part of the year was occupied, for the most part, in an intensive effort to complete the preparation for publication of monographs and journal articles by Dr. Francis G. Benedict before his retirement as Director. This was most successfully accomplished, and the several publications have gone through the press.

The experimental work has continued largely in the same fields of research as have already been in progress for a number of years. In spite of a considerable amount of observation on the biological variations in basal metabolism, there are still gaps in the data and excellent leads for future study, particularly of those animal species in which there are large variations in size and configuration. Conspicuous examples are found in the rabbit and the dog. The study already made of the metabolism and the heat regulation of the woodchuck points to the importance of continuing such investigation on those animals, like the woodchuck, that have seasonal changes in their metabolic levels and that seem to form a connecting link between homoiothermic and poikilothermic animals.

There is at present a renewed interest in bodily heat regulation, as evidenced by the number of recent publications concerned with the distribution of heat elimination, the skin and the body temperature. The present increasing use of methods of air conditioning, particularly air cooling (some of which are far from satisfactory either from the physiological standpoint or from the standpoint of comfort), indicates the need of more knowledge of human heat regulation in response to rapid and unusual changes in environmental conditions. The past experience of the Nutrition Laboratory in the studies of skin and body temperatures and its experimental equipment, particularly the emission calorimeter for humans, provide conditions for a comparative study of heat production and heat elimination which would be of value in understanding the physiological processes of the body when there is a necessity for rapid adaptation to changes in environmental conditions.

Most of our food supply is in the form of carbohydrates in common foods. An index of the supply and utilization of the foodstuffs in the body is furnished by the respiratory quotient, the level of which is influenced predominantly by the carbohydrates. Consequently part of the experimental program is to carry on such studies as may be of assistance in interpretation of the respiratory quotient and of value in indicating the availability of carbohydrates, both as a source for furnishing fuel for immediate combustion and as a source of glycogen reserve. Several studies have been made during the past year dealing with the factors affecting the respiratory quotient and particularly the effects of sugars and foodstuffs on the time relationships in the changes in the quotient and the height to which the quotient is increased after ingestion of these foods. Such studies not only have academic interest but also are of practical interest, especially in medicine where there is need for an index as to the glycogen supply and the availability of carbohydrates in the body.

¹ Situated in Boston, Massachusetts.

STAFF NOTES

Dr. Francis G. Benedict retired on November 1, 1937, as Director of the Nutrition Laboratory and was appointed a Research Associate of the Carnegie Institution. Between March 2 and March 8, 1938, addresses were given by him under the auspices of Sigma Xi at the Ohio State University, the Michigan State College, the College of Medicine of the University of Illinois, the University of Colorado, the University of Washington, and Purdue University. The subject of these addresses was "Animal metabolism from the mouse to the elephant." In some instances Dr. Benedict also gave an additional talk on "What the research worker may learn from the magician."

Dr. T. M. Carpenter gave a paper entitled "The effect of urea on human respiratory exchange and alveolar air" on September 7, 1937, at the semi-annual meeting of the American Chemical Society at Rochester, New York. On March 11, 1938, he lectured to the students in biochemistry at the Harvard Medical School on "Basal metabolism and specific dynamic action." On April 2, at the annual meeting of the American Physiological Society at Baltimore, Maryland, he presented a paper, with Dr. C. G. Hartman of the Department of Embryology as co-author, on "The effect of hexoses on the respiratory quotient of the rhesus monkey." On March 30, 1938, Dr. Carpenter was elected Vice-president of the American Institute of Nutrition at its annual meeting, and on May 13 he was elected Chairman elect (Vice-chairman) of the Northeastern Section of the American Chemical Society.

A conference among members of the Institution's Division of Animal Biology was held at the Nutrition Laboratory on February 5, 1938, at which were present A. F. Blakeslee, T. M. Carpenter, W. M. Gilbert, C. G. Hartman, R. C. Lee, O. Riddle, and G. L. Streeter. Guests were E. G. Ritzman and N. F. Colovos of the Laboratory for Animal Nutrition at Durham, New Hampshire; M. O. Lee, H. C. Trimble, and G. B. Wislocki of the Harvard Medical School; and H. F. Root and Priscilla White of the New England Deaconess Hospital.

From time to time groups of students from various schools have visited the Laboratory and been conducted around the building. These have included students from the Harvard Medical and Dental Schools, graduate students in nutrition from the Massachusetts State College at Amherst, and students from Nason College at Springvale, Maine.

INVESTIGATIONS IN PROGRESS

Observations on the marmot. The study of the metabolism of the marmot and of factors related to the metabolism was terminated in the spring of 1937. There remained, however, certain lacunæ in the data secured, particularly with regard to the body temperature gradient and the respiratory quotient during hibernation. These two problems have been studied during the past year by R. C. Lee, assisted by G. Lee.

Metabolism of the normal rabbit. The study of the heat production as influenced by differences in size within the same species has been continued under the direction of R. C. Lee (assisted by G. Lee, C. Hatch, and H. B.

Lee) and now includes observations on rabbits ranging in weight from 1.5 kg. (Polish) to 7 kg. (Flemish Giant). Emphasis has been laid upon the effect of environmental temperature on the metabolism and the adaptation of the animal to various controlled environmental conditions after living under such conditions for a long time. A special study of the body temperature and the factors affecting it has been made. A group of wild cottontail rabbits have furnished considerable data for comparison of the wild with the domestic animal.

Metabolism of the narcotized rabbit. By the use of nembutal the cell temperature of rabbits has been lowered to approach the condition obtaining with hibernating marmots. With rabbits thus narcotized observations on heart rate, respiration rate, body temperature, respiratory quotient, and metabolism have been carried out by R. C. Lee, assisted by G. Lee, for the purpose of studying the factors that control the heat production and the body temperature.

Basal metabolism in experimentally produced atherosclerosis. For some time it has been known that experimentally atherosclerosis can be produced in animals by the feeding of cholesterol and that if thyroxin or thyroid extract is given simultaneously, atherosclerosis is not so likely to take place or may even be prevented. This suggests that the thyroid gland may play a rôle in controlling the development of this disease. For a number of years Dr. Timothy Leary, Medical Examiner of Suffolk County, Massachusetts, has been studying experimentally the production of atherosclerosis in rabbits by cholesterol feeding, with special reference to its pathology. During the past year the Nutrition Laboratory has begun a cooperative study with him on the basal metabolism of these animals. The basal metabolism has already been determined of a group of rabbits to be fed cholesterol and a group to serve as normal controls. Repetition of these determinations will be made after several months of feeding cholesterol, as a control on the level of the thyroid activity. The basal metabolism studies have been under the supervision of R. C. Lee, assisted by G. Lee.

Skin temperature of domestic animals. In cooperation with Professor E. G. Ritzman, at the University of New Hampshire, and under his direction, the skin temperatures of a pig, a goat, a sheep, and a ram were measured under various environmental conditions by R. C. Lee and N. F. Colovos. These measurements contribute to a study of heat loss and the conservation of heat by the animal body.

Metabolism studies with domestic animals. The profitable cooperative research on the metabolism of domestic animals, which has been carried on for a number of years with Professor E. G. Ritzman at the University of New Hampshire, was terminated January 1, 1938, so far as direct connection administratively between the Nutrition Laboratory and the University of New Hampshire is concerned. Professor Ritzman was then appointed Research Associate of the Carnegie Institution of Washington.

*Metabolism studies on the *Macacus rhesus*.* The metabolism measurements on the *Macacus rhesus*, which have been carried on for several years with the colony at the Department of Embryology at Baltimore with the cooperation of Dr. George L. Streeter and Dr. Carl G. Hartman, were brought

to an end on October 1, 1937. The calculations and completion of the material for a report are in progress at the present time.

Respiratory quotient of the Dalmatian dog. The protein metabolism of the Dalmatian dog is characterized by a much larger urinary excretion of uric acid as an end product of the metabolism than occurs with any other breed of dog. Through the cooperation of Dr. Harry C. Trimble of the Department of Biochemistry of the Harvard Medical School, and with the assistance of B. James and M. Stankard, metabolism studies have been made on a dog of this breed with particular reference to the partition of the total metabolism in relation to the respiratory quotient and the nitrogenous excretion in the urine during fasting and after feeding of meat.

Effect of ingestion of hexoses on the respiratory quotient of the Macacus rhesus. An unusual opportunity for a study of the effect of sugars on the respiratory quotient of primates was afforded by the colony of rhesus monkeys at the Department of Embryology at Baltimore. After the measurements of basal metabolism were terminated, a special intensive series of respiration experiments was made in cooperation with Dr. C. G. Hartman, in which the respiratory quotients were determined after ingestion of glucose, fructose, or galactose. In the experiments with galactose the urinary excretion of the sugar was also determined. The respiration experiments were made by B. James. A preliminary report (see page 82) of this research has been presented to the American Physiological Society.

Effect of ingestion of hexoses on the respiratory quotient of the goat. There is evidence that metabolism of carbohydrates in the ruminant is different from that in other animal species, as is shown by the marked production of methane when ruminants are on full feed. In the general investigation on the effects of sugars on the respiratory quotients of animals it is obvious that this species should be included. Through the cooperation of Professor Ritzman, studies on the effect of ingestion of hexoses on the respiratory quotient of the goat have been initiated and are in progress.

The electrical method of gas analysis. For a number of years it has been evident that the immediate need in the advancement in the technique of metabolism studies is for a more rapid method of determination of the composition of the gases that have to be studied in measurements of respiratory exchange. During the past year an apparatus has been developed and described by Professor A. K. Noyons, of the University of Utrecht, Holland, for the determination of the changes in composition of gases by measurement of changes in resistance of a heated wire due to the changes in the surrounding gaseous atmosphere. Construction of a similar apparatus has been started at the Nutrition Laboratory by V. Coropatchinsky, for the purpose of comparing this apparatus with the standard form of gas analysis apparatus, in which the composition of gases is determined by volumetric analysis.

Prevention of respiratory failure in newborn infants. Dr. Priscilla White, of the Joslin Clinic and the New England Deaconess Hospital, in studying the prevention of respiratory failure in newborn infants of diabetic mothers, has continued the use of the Nutrition Laboratory's helium-oxygen chamber. R. C. Lee and G. Lee have assisted in this work.

Metabolism in diabetes. In cooperation with Dr. Howard F. Root of the

New England Deaconess Hospital and with the assistance of R. C. Lee and B. James, a special study was made of a patient who not only had diabetes but also had had acromegaly at some time during the past. The study of the metabolism during diabetic coma is to be continued as opportunity offers.

Maximum temperature of expired air as an index of body temperature. The apparatus for determining the maximum temperature of the expired air (mentioned in Year Book No. 34, p. 65) has been further developed and the relationship of the maximum temperature of the expired air to the body temperature established. This apparatus is particularly adapted for measuring the body temperatures of large groups of humans in that measurements can be made at the rate of four per minute. Numerous measurements of normal subjects were made at the Nutrition Laboratory, and a special series of measurements of patients with artificially produced fever was made at the Boston Psychopathic Hospital through the cooperation of Dr. H. C. Solomon and Dr. I. Kopp. This research was conducted by R. C. Lee, assisted by H. B. Lee.

Effect of ingestion of foods on the human respiratory quotient. The carbohydrates in the human diet are not, for the most part, derived directly from pure sugars but from mixtures of simple and hydrolyzable sugars and starches. Such combinations are found in vegetables, cereals, fruits, and nuts. The rise in the respiratory quotient is one index of the availability of carbohydrates to the body and the rapidity with which they are burned. Experiments were made on the changes in the respiratory quotient with respect to height of the rise and the time relationships, in which single portions of common foods (cooked and raw vegetables, bread, nuts, and fruits) were given that contained approximately 25 grams of carbohydrates each. Control experiments with 25 grams of glucose or of cane sugar served for comparison. Samples of the foods given are to be analyzed for reducing sugars, hydrolyzable sugars, and starches, to compare with the actual changes in respiratory quotient and to determine which of the carbohydrates are most effective in causing a rise in the respiratory quotient. The respiration experiments are being carried out by B. James and the chemical analyses by M. Stankard.

LITERARY WORK

A paper on "The maximum temperature of expired air as a rapid measure of human body temperature" has been written by Dr. and Mrs. Benedict and Mr. and Mrs. R. C. Lee and has been accepted for publication by the *New England Journal of Medicine*. A manuscript on the body temperature of the normal rabbit and factors affecting it is in the process of preparation by R. C. Lee. The large amount of proofreading and editorial work has had the capable supervision of the editor, Elsie A. Wilson.

PUBLICATIONS

- (1) *The basal metabolism and urinary nitrogen excretion of Chinese, Manchus, and others of the Mongolian race.* Francis G. Benedict, Lan-Chen Kung, and Stanley D. Wilson. *Chinese Jour. Physiol.*, vol. 12, pp. 67-100 (1937).

Basal metabolism measurements on 120 adult Mongolians, chiefly Chinese and Manchus, showed as with other human races an increase in total heat production with increasing weight, a decrease in heat production per kilogram the larger the

individual, a decrease in total heat production with advancing age among subjects of the same weight, and a lower metabolism of the women than of the men. Pulse rates and nitrogen output per kilogram of body weight were in general the same as noted with Caucasians. The decrease in total heat production per year increase in age averaged about the same for the male Chinese as for Caucasian men (7 calories) but averaged 5 calories for the Chinese women as compared with 2.3 calories for Caucasian women. No marked influence of Western civilization upon the metabolism of those Chinese who had adopted Western ways of living was apparent. The basal metabolism of these Chinese as a whole was, by every method of comparison, lower than that noted with Caucasians, the difference being more pronounced with the men than with the women.

- (2) *Die Bedeutung des Körperfettes für die Wärmebildung im Organismus.* Francis G. Benedict and Robert C. Lee. *Biochem. Ztschr.*, vol. 293, pp. 405-409 (1937).

Within the weight range from 2.5 to 7.5 kg. adult geese had a total heat production that increased in a straight-line relationship with the increase in weight. Inasmuch as in the surfeit feeding of adult geese the protein content of the body is only slightly increased, the increase in heat production of these geese with increasing weight was the result of an increased storage of fat. This finding is supported by observations on the basal metabolism and body composition of 8-g., 21-g., and 60-g. mice. Body fat should, therefore, not be considered as metabolically inert but as an energy-demanding substance.

- (3) *Basal metabolism of rats in relation to old age and exercise during old age.* Francis G. Benedict and Henry C. Sherman. *Jour. Nutrition*, vol. 14, pp. 179-198 (1937).

With a group of adult rats (non-exercised) of different ages but of the same weights the basal 24-hour heat production was somewhat higher in old age than in middle life. With a group of adult rats (non-exercised) of different weights as well as ages, however, the heat production was relatively constant at the older ages. The total heat production of any one rat decreased slightly with advancing age, but at the same time there was a relatively larger (although also small) decrease in body weight, so that the metabolism per unit of weight and per unit of surface area increased slightly. The body temperature tended to decrease in old age (after 800 days of age), and in very advanced age the decrease amounted to about 2° C. Middle-aged male rats, not previously exercised, could not adjust themselves to strenuous exercise begun so late in life, lost weight rapidly, and usually died. Middle-aged female rats, not previously exercised, were apparently benefited by the exercise, which tended to lower their basal metabolism. It is suggested that the organism of the exercised rat is freed by muscular exercise from a middle-age restlessness or chronic useless tenseness and is able to relax better in rest periods.

- (4) *Race: A factor in human metabolism.* Francis G. Benedict. *Proc. Amer. Philos. Soc.*, vol. 78, pp. 101-110 (1937).

This paper summarizes the metabolic findings of a racial survey made by the Nutrition Laboratory and its collaborators. Oriental races in general were found to have a metabolism somewhat lower than that of Caucasians in the United States. South Indian women in Madras had a metabolism 17 per cent below the Caucasian prediction standards, and this was further depressed about 10 per cent during deep sleep. In striking contrast to the low metabolism of the majority of the Oriental races were the high metabolism of the Maya (+8 per cent) in Yucatan and the Miao males (+16 per cent) in Szechwan, China, although in both instances low pulse rates were observed. With Manchus of the laboring class, both males and females, lower values for total heat production were found than with Chinese laborers of the same weight, age, and sex. This survey has established that there are marked differences

in the basal metabolism of different human races, probably ascribable solely to the racial factor and not to differences in climate and diet, and that there may even be a racial difference in metabolism within the Oriental race itself.

- (5) *Lipogenesis in the animal body, with special reference to the physiology of the goose.* Francis G. Benedict and Robert C. Lee. Carnegie Inst. Wash. Pub. No. 489 (1937). ix + 232 pp., 30 figs., 35 tables.

To study the metabolism during the transformation of carbohydrate into body fat (lipogenesis) adult geese were fed surfeit amounts of a corn-meal mixture, following which measurements were made of the respiratory exchange and the heat production. The latter was determined directly by means of an emission calorimeter, described in detail. The respiratory exchange measurements, the techniques for which are also described, included the oxygen consumption, the carbon dioxide elimination, the cleavage carbon dioxide, and the respiratory quotient. The physiology of the goose was also studied under normal basal conditions and during prolonged fasting, and observations were made of the rectal temperature, heart rate, respiration rate, insensible perspiration, water-vapor output, chemical composition of the body, and zone of thermic neutrality. By surfeit feeding of carbohydrate the oxygen consumption of the goose may be increased 50 to 100 per cent and the carbon dioxide elimination 100 to 400 per cent. The respiratory quotient may increase to 1.48. Maximum values for all three factors and also for cleavage carbon dioxide occur within 1 to 3 hours after surfeit feeding and persist for about 3 hours, but the usual basal values are found again within 24 hours. According to the data obtained in the calorimeter experiments, when carbohydrate is converted into fat after surfeit feeding and the respiratory quotient remains at a constant high level of about 1.40, the relationship between the simultaneously measured oxygen consumption and the heat production is the same as that during the combustion of pure carbohydrate at a respiratory quotient of 1.00. Hence when the respiratory quotient is above 1.00, the heat production can be calculated indirectly with sufficient accuracy from the measured oxygen consumption by use of the factor of 5.047 calories per liter of oxygen.

- (6) *Effects of thyroidectomy and thyroid feeding in geese on the basal metabolism at different temperatures.* Milton O. Lee and Robert C. Lee. *Endocrinology*, vol. 21, pp. 790-799 (1937).

The metabolism (per $10W^{3/4}$) of twelve normal geese was 25 per cent higher at 11° C. than their basal rate at 23° C. Four of these geese, after thyroidectomy, had a metabolism, on the average, 51 per cent higher at 11° C. than their average level at 23° C. The metabolism of these thyroidectomized geese was 33 per cent lower at 23° than that of the normal birds but only 15 per cent lower at 11° C. The thyroidectomized goose can make metabolic adjustments to low environmental temperatures as great in magnitude as the normal goose. The thyroid gland is, therefore, not necessary to the goose for thermogenesis in adaptation to a cold environment.

- (7) *Further observations on the physiology of the elephant.* Francis G. Benedict and Robert C. Lee. *Jour. Mammal.*, vol. 19, pp. 175-194 (1938).

Supplementing the detailed study of the physiology of the elephant reported in 1936 (Carnegie Inst. Wash. Pub. No. 474), further observations were made, particularly to fill obvious lacunæ in the first investigation. These deal with the muscular activity of the elephant, the sleeping positions assumed, the teeth, the habits of eating and chewing, the hearing, the reaction to rats and mice, the maximum possible weight, measurements of height, microscopic examinations and temperature measurements of feces and urine, skin temperature measurements, determi-

nations of methane in the intestinal gases, and observations on respiration rate and heart rate. Men in charge of zoological parks and circuses are urged to notify scientists when elephants are to be killed, so that further studies can be made when these animals are dissected.

- (8) *The nutritional physiology of the adult ruminant.* Ernest G. Ritzman and Francis G. Benedict. Carnegie Inst. Wash. Pub. No. 494 (1938). vi + 200 pp., 3 pls., 3 figs., 55 tables.

In this monograph are reported the results of a cooperative investigation by the New Hampshire Agricultural Experiment Station and the Nutrition Laboratory, dealing primarily with the nutritional physiology of the cow but supplemented by observations on steers, bulls, sheep, goats, and horses. Eleven cows were studied under maintenance conditions of feeding, over periods ranging from 4 months to nearly 4 years, and with these animals 49 digestion balance experiments (each one month long) were made. At the end of each digestion experiment the respiratory exchange was measured, first with the cows on feed and then on the fourth and fifth days of fasting. The rations fed were hay alone (six kinds, of early and late cutting), concentrate alone (corn meal or linseed oil meal), or a mixture of concentrate and bran. The cows (Holsteins and Jerseys) were all adults and in most instances dry and not pregnant, although a special study was made of two cows during pregnancy and lactation. The first section of the monograph deals with digestibility of roughages and of concentrates, weight and character of fill, methane production, chemical composition of excreta, nitrogen and energy balances, water-vapor output, insensible perspiration, heart rate, respiration rate, and body temperature. In the second section the conditions prerequisite for basal metabolism measurements on ruminants are outlined and the results of such measurements on the cows are discussed. Great variability was noted in the metabolism of one and the same cow (dry and not pregnant), changes of 30 to 74 per cent occurring within as short a time as six weeks without marked difference in nutritive condition. The cause of this variability is considered to be of hormone origin, due to selective breeding for milk production. The percentage increases in metabolism above the basal level due to the stimulating effects of the ingestion of the different roughages (predominantly carbohydrate in nature) were as great with these cows as the increases following protein ingestion noted with dogs and humans. In the last section of the book the factors to be considered in evaluating the utilization of food energy by cattle are discussed, especially the dynamic stimulus of food and the great variability in basal metabolism. The digestible energy, the net energy, and the metabolizable energy as measured in the digestion balance experiments are also discussed, and in the concluding pages there is a brief consideration of the efficiency of metabolizable energy for maintenance and for milk production.

- (9) *Hibernation and marmot physiology.* Francis G. Benedict and Robert C. Lee. Carnegie Inst. Wash. Pub. No. 497 (1938). x + 239 pp., 2 pls., 11 figs., 58 tables.

A metabolic study of the marmot was made to secure information regarding the physiology of the animal itself and for comparison with other warm-blooded animals that do not hibernate and with cold-blooded animals, for in its awake and asleep periods it resembles somewhat these two types of animals, respectively. Measurements of body weight changes, insensible perspiration, heart and respiration rates, rectal temperature, respiratory exchange, and water-vapor output were made on 48 marmots, at different environmental temperatures, in the non-hibernating and hibernating states, and in the transitional stages of entering and awakening from hibernation. Several marmots were drugged with nembutal and subsequently exposed to a cold environment, others were subjected to carbon dioxide narcosis and

cold, and the measurements on these were compared with those on the animals hibernating under normal conditions. The urines voided by four marmots while fasting and hibernating were analyzed to determine the partition of urinary nitrogen. During hibernation there was no marked change in the character of the respiratory exchange, the true combustion respiratory quotient was one of fat, and the protein metabolism underwent no qualitative alteration. When not hibernating, the marmot has a labile basal heat production and rectal temperature, but when its body temperature is 36.9° C. its basal metabolism averages about 400 calories per $10w^{3/4}$ per 24 hours. This is much higher than that of any cold-blooded animal of the same size at a body temperature of 37° C. but is considerably lower than the metabolism of other warm-blooded animals of the same size thus far studied. The hibernating marmot resembles the cold-blooded animal in that, when exposed to a low environmental temperature, its rectal temperature becomes very low and its respiration rate slow, but its heat production per $10w^{3/4}$ even at the minimum level is two or three times that of a snake of the same size having the same low body temperature. The causes and theories of hibernation are discussed, and a digest of the main findings of the investigation is presented.

- (10) *Vital energetics: A study in comparative basal metabolism.* Francis G. Benedict. Carnegie Inst. Wash. Pub. No. 503 (1938). vii + 215 pp., 46 figs., 4 tables.

The basal metabolism measurements on all the animal species that have been studied at the Nutrition Laboratory during the past three decades are analyzed in this report from the standpoint of comparisons within the same and between different species. Only adult animals are considered. These ranged in size from the 8-g. dwarf mouse to the 4000-kg. elephant. The prerequisites for comparable measurements of basal heat production are outlined, and consideration is given to the bases for intraspecific and interspecific comparisons of animals of different sizes, with particular reference to the metabolically inert factors affecting body weight and the problems of measuring or calculating the true surface area of the body. For each warm-blooded species a chart is given, in which the total 24-hour heat production of each animal measured is plotted with reference to its body weight and a curve is drawn through the plotted data to indicate the general trend of the metabolism with increasing weight. These intraspecific comparisons represent eighteen species of mammals, including humans, seven species of domesticated birds, and several wild birds. The interspecific comparisons are based upon a series of charts for progressive weight groups and also for the entire weight range from 8 g. to 4000 kg., in which are assembled the curves representing the trends of the average metabolism of the different species referred to weight and expressed as total heat production, heat production per kilogram, and heat production per $10w^{3/4}$. The measurements at environmental temperatures of 16° and 28° C. are compared, and there is a critique of the surface area concept. The measurements are also referred to different powers of the body weight. Finally, warm-blooded animals are compared with cold-blooded animals both at low cell temperatures and at 37° C. Emphasis is laid upon the value of basing metabolism comparisons upon the *total* heat production of species of the *same* body weight, thus eliminating the problem of how to equalize differences in weight. Discussion is given of the factors that may contribute to metabolic differences within and between species, such as body structure, composition, and covering, cell temperature, cell enzymes, brain weight, and blood. It is recommended that one should turn from a consideration of heat loss to a consideration of heat production, that the lack of uniformity in heat production should be recognized, and that the differences in metabolic intensity or vital energetics should be associated with differences in body configuration and composition and with differences in the morphology, chemistry, and particularly the distribution of the blood.

- (11) *The partition of urinary nitrogen of fasting and hibernating woodchucks (Arctomys monax)*. Thorne M. Carpenter. Jour. Biol. Chem., vol. 122, pp. 343-347 (1938).

One specific detailed example is given of the results of a study of the partition of urinary nitrogen in the urine of a marmot. The details of other studies are given in the monograph cited on page 80 of this report.

- (12) *Effects of hexoses upon the respiratory quotient of the rhesus monkey*. Thorne M. Carpenter and Carl G. Hartman. Amer. Jour. Physiol., vol. 123, p. 32 (1938).

Abstract. (See page 76.)

- (13) *The effect of urea on the human respiratory exchange and alveolar carbon dioxide*. Thorne M. Carpenter. Jour. Nutrition, vol. 15, pp. 499-512 (1938).

Ingestion of 30 and 40 g. of urea caused marked rises in the alveolar carbon dioxide and in the respiratory quotient during 3 to 3½ hours after ingestion, but no change in the oxygen consumption, as compared with these same factors in control experiments. The simultaneous increases in alveolar carbon dioxide and respiratory quotient are the result of the alkalosis following the ingestion of urea. As the alveolar carbon dioxide is also increased by the gastric secretion following the ingestion of protein, there may be two causes for the alterations in the respiratory quotient from the true respiratory quotient of protein, one the gastric secretion containing hydrochloric acid and the other the urea that ultimately results as a metabolic product of the transformations of protein in the body.

- (14) *The effect of ingestion of alcohol on human respiratory exchange (oxygen consumption and R. Q.) during rest and muscular work*. Thorne M. Carpenter and Robert C. Lee. Arbeitsphysiologie, vol. 10, pp. 130-157 (1938).

Measurements of the respiratory quotient and the oxygen absorption after ingestion of 30 and 50 cc. of alcohol, respectively, indicated that the metabolism of alcohol proceeded at about the same rate, irrespective of whether the subject was resting or exercising on a bicycle ergometer. That muscular work does not increase the combustion of alcohol was also demonstrated by the calculations of the changes in the katabolism of carbohydrate and fat in the periods of work and recovery following alcohol ingestion. There was no summation of the separate effects of alcohol and muscular work when both these factors were superimposed upon the basal metabolism. The efficiency of performance of work (relation between the heat equivalent of the work performed and the energy expenditure) was not the same in experiments with alcohol ingestion as in experiments without alcohol ingestion.

- (15) *The effect of muscular work on the amounts of alcohol in urine, expired air, and blood, after its ingestion by man*. Thorne M. Carpenter and Robert C. Lee. Arbeitsphysiologie, vol. 10, pp. 158-171 (1938).

Exercise on a bicycle ergometer at varying rates of speed for periods of 30 minutes to 2 hours after ingestion of 30 and 50 cc. of alcohol did not appreciably alter the concentration of alcohol in urine, blood, or expired air, or the amount of alcohol eliminated per liter of carbon dioxide exhaled, as compared with these same factors during rest. The amounts of alcohol in the ventilating air current of the respiration apparatus were greater during exercise than during rest and were greater the severer the work, because of the increased total ventilation of the lungs. However, when the work ceased, the amounts approached those found in the same time interval after ingestion in the rest experiments. In the rest experiments from 0.4 to 0.7 per cent of the total alcohol ingested was eliminated in the ventilating air current and from 0.8 to 1.6 per cent was eliminated in the urine and expired air. In the work experiments these percentages were 0.9 to 1.6 and 1.1 to 2.1, respectively. The

disappearance of alcohol through these paths plays only a small rôle in reducing the amount of alcohol in the body.

- (16) *The effect of muscular work on the metabolism of man after the ingestion of sucrose and galactose.* Thorne M. Carpenter and Robert C. Lee. *Arbeitsphysiologie*, vol. 10, pp. 172-187 (1938).

Measurements of the respiratory exchange were made in 3-hour experiments after ingestion of 70 g. of sucrose or 50 g. of galactose, with the subject at rest and at work. The exercise (pedaling a bicycle ergometer) resulted in a greater combustion of cane sugar but not of galactose. It is questionable whether muscular work has any effect on the metabolism of galactose except apparently to accelerate the reaction after the ingestion of the sugar. There was no summation of the effect of the ingestion of the sugar (either sucrose or galactose) at rest and the effect of muscular work without sugar when the sugar ingestion was accompanied by work. The efficiency of performance of work was better when sugar was ingested than when it was not and was slightly better after galactose than after sucrose. More of the ingested sugar was utilized in the more intense work.

TORTUGAS LABORATORY

D. H. TENNENT, EXECUTIVE OFFICER

PAUL S. CONGER, ASSISTANT EXECUTIVE OFFICER

During the summer of 1938 the Tortugas Laboratory was open from June 2 to August 9.

The following investigators studied at the Laboratory during the season:

P. L. Bailey, Jr., College of the City of New York. Regeneration in sabellids. June 30 to August 9.

N. J. Berrill, McGill University. Budding in polystyelid ascidians. June 16 to June 28.

F. J. Brinley, North Dakota Agricultural College. Origin of muscular movements in fish embryos. June 16 to August 9.

Leonard B. Clark, Union College. Swarming of the Atlantic palolo. Habits of the basket star. June 16 to July 26.

Paul S. Conger, U. S. National Museum and Carnegie Institution of Washington. Investigations on diatoms. June 2 to August 9.

B. R. Coonfield, Brooklyn College. The development and coordination of melanophores in embryos of *Pomacentrus*. June 30 to August 9.

Hugh H. Darby, College of Physicians, Columbia University. Continuation of studies of regeneration in Crustacea. June 30 to August 9.

John H. Davis, Jr., Southwestern College. Studies of mangroves and changes of strand flora. June 16 to June 28 and July 28 to August 9.

Walter N. Hess, Hamilton College. Reactions to light and the photoreceptors in the spiny lobster. Habits of the basket star. Swarming of the Atlantic palolo. June 16 to July 28.

Norris Jones, Swarthmore College. Investigations on ascidians. June 30 to July 26.

Balduin Lucké, The School of Medicine, University of Pennsylvania. Studies on tumors in cold-blooded vertebrates. June 2 to June 28.

Gordon Marsh, State University of Iowa. Further studies on the electrical behavior of *Valonia*. June 2 to August 9.

Paul A. Nicoll, University of Chicago. The response of ascidian larvæ toward certain hormones. June 30 to August 9.

Fernandus Payne, Indiana University. Study of the effect of anterior pituitary hormones on the development and discharge of the sex cells in *Ptychodera bahamensis*. Observation of *Amphioxus* larvæ. June 30 to August 9.

Harold H. Plough, Amherst College. Investigations on ascidians. June 30 to July 28.

Gordon A. Riley, Yale University. Study of the quantity of plankton in tropical waters. July 14 to August 9.

Vance Tartar, Yale University. Regeneration in the starfish *Linckia* and in the protozoan *Condyllostoma*. June 30 to August 9.

D. H. Tennent, Bryn Mawr College. Effect of intensity of light on photodynamic reactions. June 16 to July 28.

REGENERATION IN SABELLIDS

P. L. BAILEY, JR.

The problem originally intended was a study of the effect of chemical solutions on regeneration in the littoral oligochaete, *Pontodrilus*, which has previously been reported as remarkably adjusted to marine existence. The organism proved not to be especially suited to experimental work with solutions. Mortality of individuals kept in sea water, or in sea-water solutions

of dinitrophenol, colchicine, and thyroxine, was very great; regeneration of lost parts was too slow to be of value in the time available; and failure of the wound to close properly caused in many control and experimental animals a peculiar bulbous abnormality, without growth of new segments.

The sabellids (genera and species of which I have not completely identified to date) found plentifully in the moat at Fort Jefferson, however, proved to be far more satisfactory. The major portion of the work was spent adjusting different strengths of solution to these worms. Individuals in which 40 to 50 posterior segments had been amputated failed to regenerate lost segments until after 15 days when kept in a solution of 1 grain of colchicine in 1 liter of sea water. Controls in pure sea water began to regenerate lost segments in 3 days. In less concentrated solutions the rate of regeneration was less retarded. Individuals were fixed at various stages of regeneration with the hope that histological study of the effect of the chemical on the cells will reveal further facts concerning the origin of the new tissues in the regenerative process.

A portion of the time was spent in observation and experiments on the tube-forming mechanisms of these same sabellids. It is hoped that a more detailed description of the anatomy and physiology of the process can be given than has heretofore been presented, after further experiments can be made and a histological study of preserved material can be completed.

BUDDING IN POLYSTYELID ASCIDIANS

N. J. BERRILL

The investigation relates to the general problem of the nature of inherent organization manifest in bud rudiments and regeneration blastemas. Such anlagen are apparently undifferentiated as wholes and consist usually of unspecialized cells. Polystyelid ascidians represent ideal material for studying this problem inasmuch as on the one hand they form a compact natural group with highly distinctive larval, postlarval, and adult characters, and on the other vary considerably in colony form and size, in size of constituent zooids, and in time sequences of asexual reproduction. Material was collected, studied alive, and preserved for more detailed investigation, of the forms *Polyandrocarpa tinctoria*, *Symplesma viride*, and *Botryllus nigra*. It was found that the area of the bud rudiment relative to the size of the parent zooid at the time of its appearance was closely related to the size of mature zooids and the general nature of the colony. It is also evident that the bud rudiment must be regarded as an integral part of the individual organization, and as such its development as a part of an individual is strictly comparable with features such as gill slits or heart. Further, in *Botryllus* at least, the absolute size of a bud rudiment determines the extent to which mature or immature gonads will develop at a time when the rudiment consists of a two-layered disk of unspecialized epithelial cells of ectodermal origin, irrespective of the nutritive supply of the developing bud. It is hoped that further study of this and similar material will show clearly the validity of the field or *Gestalt* concept of organization when applied to blastemas exhibiting no visible differentiation either as wholes or in their constituent cells.

STUDY OF THE ORIGIN OF MUSCULAR MOVEMENT IN FISH EMBRYOS

FLOYD J. BRINLEY

The work here reported was done at the Tortugas Laboratory from June 16 until August 9. It is a continuation of a general problem on the relation of innervation to the origin of the heart beat, peristalsis in the alimentary canal, body and fin movement. The organisms used were the embryos and newly hatched larvæ of *Pomacentrus leucostictus* and embryos of the nurse shark.

Muscular contraction or peristalsis of the smooth muscles of the alimentary canal starts in *Pomacentrus* embryos two or three days prior to hatching. It is first observed in the fore- and hind-gut and later develops in the mid-gut. Contractions occur in the fore-gut at a definite rhythm of about 24 beats per minute. Peristalsis originates in the anterior region and passes caudad, where it ceases before entering the mid-gut. Contractions of the hind-gut occur at irregular intervals and may originate at the junction with the mid-gut or at the posterior end. Contractions of the mid-gut occur less frequently and at irregular intervals. These three regions of the alimentary canal in the embryos and newly hatched larvæ behave as separate physiological units and are independent of each other in regard to muscular activity.

In older larvæ, after complete absorption of the yolk, the definite rhythm of contraction of the fore-gut is replaced by a much slower wave-like movement which occurs at irregular intervals. The amplitude of contractions of the mid- and hind-gut in the older embryos is greater than in the younger stages, and peristaltic waves which originate in the mid-gut usually continue to the hind-gut.

Injections of atropine sulfate solution (0.05 to 0.1 per cent) or ergotoxin (0.1 per cent), which depress the parasympathetic and sympathetic nervous systems respectively, have no effect on the muscular movement of the alimentary canal of the embryos or day-old larvæ. Injections of atropine into older larvæ depress peristalsis and constrict the entire gut. Ergotoxin increases muscular activity in all portions of the alimentary canal in the older embryos and dilates the mid- and hind-gut.

These reactions indicate that muscular contractions of the smooth muscles originate within the muscle but are soon controlled by the ingrowth of the autonomic nerves.

In the nurse shark body movement is first observed in 6-mm. embryos. Microinjections of curare (which blocks the transmission of impulses from motor nerves to striated muscles) does not affect muscular activity until the embryos have reached a length of 18 mm. In embryos from 18 mm. to 48 mm., curare reduces body movement to a series of single twitches at definite intervals varying from a few seconds to two minutes. In embryos larger than 48 mm. the drug completely blocks all impulses or reduces activity to slight twitches at several-minute intervals.

It appears from these results that muscular contraction of striated muscles originates in the muscle and the ingrowth of motor nerves takes place between 18 and 48 mm. During this stage body movement is largely due to impulses coming from the nervous system. When these impulses are blocked by

curare, spontaneous contractions of the muscles continue at a definite rhythm which probably is a fundamental property of all muscles. In embryos larger than 48 mm. the stimulant for contraction arises entirely in the nervous system, and conditions within the muscles are not suitable for spontaneous contractions.

A study of the effect of caffeine on the rate of heart beat in shark embryos indicates that the vagus makes contact with the heart when the embryo is about 54 mm. in length.¹ Prior to that stage, caffeine has no effect on the rate of heart beat, but in older embryos the heart shows a decided irregularity in rhythm within 2 minutes after injections of caffeine. Digitalin (0.005 to 0.1 per cent) reduces the rate of the prevagus heart, which results in stoppage within 10 to 15 minutes after injection. However, digitalin produces a slight increase in the rate of the innervated heart immediately after injection. This increase passes into a depression and finally the heart stops in diastole.

A large number of shark embryos were fixed for embryological studies.

OBSERVATIONS ON THE ATLANTIC PALOLO

LEONARD B. CLARK

Rocks sterilized and planted in 1937 on West Loggerhead and Bird Key reefs yielded young worms but no sexually mature individuals. This seems to indicate that the palolo must be more than one year old before sexual maturity.

With the cooperation of the lighthouse staff on Loggerhead Key, palolo worms were collected at frequent intervals from September 1, 1937 to June 1, 1938. This material will allow studies to be made of the regeneration and development of the sexual ends.

During the summer of 1938, twelve experiments on the effect of artificial light were carried out. By adding artificial illumination to moonlight or covering the floating cars containing the worms from moonlight, it has been found that the time of swarming was seriously disturbed. Swarming epitokes were secured at sunset, in the morning up to 10:30 a. m., and at times other than when the worms swarmed naturally. However, on July 3, when the natural swarm was very abundant over West Loggerhead reef, a single epitoke was found in each of four cars, each car having been submitted to a different light procedure. Also on July 9 a swarm occurred in each of seven different cars, likewise having different illumination. Thus, although the amount and duration of illumination does influence swarming, the possibility of a hormonal substance diffusing in the water cannot be entirely ruled out.

Metabolism experiments were carried out with parts of mature worms to determine any metabolic gradient which might be present. Usually the complete worm was divided into five parts. The first consisted of the anterior half of the atoke, the second of the posterior half of the atoke, the third of the anterior half of the sexual portion of the epitoke, the fourth of the posterior half of the sexual portion of the epitoke, and the last of the asexual posterior portion of the epitoke.

¹ Brinley, *Physiol. Zool.*, vol. 4, pp. 527-537 (1932).

Almost invariably the order of decreasing metabolic rates for the above pieces was 5, 3, 4, 1, 2. In every case the asexual posterior tip of the epitoke had the highest metabolism. This may be significant in view of the fact that the sexual end swims with the posterior end foremost and the swimming movements originate at the posterior end.

SWARMING OF THE PALOLO WORM (*EUNICE FUCATA*) UNDER NATURAL CONDITIONS WITH OBSERVATIONS ON REACTIONS OF FREE LIVING SEXUAL ENDS

LEONARD B. CLARK AND WALTER N. HESS

Systematic daily tows were made over West Loggerhead and Bird Key reefs from June 20 to July 25, 1938. Over West Loggerhead reef, newly laid palolo eggs were found daily from June 21 to July 4 and on July 7, 11, 14, 15, with eggs fairly numerous on June 22 and very abundant on July 3. On these latter two dates swarming epitokes were observed.

Over Bird Key reef newly laid eggs were found on June 23 and daily from June 28 to July 5, July 7 to 11, and July 13 to 16 inclusive. An immense swarm occurred on July 15. On June 24 and July 16 freshly laid eggs were fairly numerous but on the other days eggs were few in number.

The third quarter of the June moon occurred on June 21, the first and third quarters of the July moon occurred on July 4 and 20 respectively. Unlike any previous record of swarming, the great swarm over Bird Key reef on July 15 occurred five days before the third quarter of the moon.

Comparative studies were made of worms in rocks from West Loggerhead and Bird Key reefs. In general, as the total number of eggs laid increased, the percentage of worms with sexually mature epitokes decreased.

During the swarms over West Loggerhead reef observations were made on the time of onset of the swarm, progress of the swarm, and intensity of light causing bursting of the epitokes with release of sex products. In the laboratory studies were made on threshold intensity for orientation of free-swimming epitokes.

In the swarm on the night of July 2 and morning of July 3 the first epitoke was observed at 9:30 p.m. The number of swarming individuals increased to a maximum at 3:40 a. m. and then decreased slowly to sunrise. After sunrise the decrease in numbers was rapid with the last epitoke observed bursting at 6:09 a. m., when daylight reached an intensity of 1095 foot-candles. Sexually exhausted individuals were swimming until after 7:00 a. m.

During the early part of the swarm males predominated, while in the later phases females were more numerous.

Swarming epitokes varied more than a thousandfold in the intensity of light necessary to cause bursting. The intensity necessary is related to the rate of increase of intensity, degree of dark adaptation, and the length of time after the epitoke became free.

Swarming epitokes orient to light, the threshold varying from 0.0005 to 0.01 foot-candle. Individuals swim in a straighter path with smaller spirals in a strong light than in weaker illumination.

Any piece of epitoke long enough to swim will orient and move toward a source of light with the posterior end facing the light.

DIATOM INVESTIGATIONS

PAUL S. CONGER

Preliminary examination was made of about 60 daily plankton samples and 30 other miscellaneous diatom gatherings, and these were preserved for further detailed study. The examination indicated that there was comparatively little change either in kind or in quantity of diatoms during the ten-week period, although some species did come in and others dropped out. It was also evident that there was some slight increase in abundance of diatoms in the plankton after a heavy wind had stirred up the waters, which lasted for a period of two to four days after the storm subsided.

Detailed studies were made of the morphology and reproduction of a very unusual and important new species of *Amphora* which composed from 20 to 40 per cent of the diatom plankton, and which proved for several reasons to be quite ideal for such studies.

Single-specimen cultures of a number of species were maintained by a specially devised method for a period of about six weeks in an attempt to determine the length of life of these forms, and changes which occur during aging of the diatoms. Interesting results were obtained but the small number that time and facilities afforded make this study necessarily preliminary to further more extensive ones. Another species of *Amphora* of unique and characteristic reproduction was carried through several division periods.

Intensive observations and experiments on several diatom species by hitherto unused methods gave very interesting information relative to the method of movement in diatoms which it seems to the writer cleared a number of misunderstandings and definitely furthered our knowledge regarding this old and puzzling question.

Silica analyses were made of several sediments in a study of the diatom-silica relationships in these highly carbonaceous waters, where silica is very conspicuously deficient.

Drawings were partially completed and some manuscript written up on these several phases of diatom research.

THE DEVELOPMENT AND COORDINATION OF MELANOPHORES IN EMBRYOS OF POMACENTRUS

B. R. COONFIELD

This report is concerned with progress made during a preliminary study of the reaction of the melanophores of *Pomacentrus* embryos. The embryos were found attached to the inner surface of unoccupied conch shells. Usually embryos of any stage of development from the early cleavage stage to the hatching stage could be found on a single conch shell. These embryos were removed easily from the shell, since they develop in a capsule, and they were easily kept in the laboratory.

It was necessary first to observe the appearance of the melanophores in these embryos. When the embryos reached the twelve-somite stage in development two pigment spots appeared in the head region, one on each side and above the future nares. Soon after this other melanophores ap-

peared dorsally in the mid-body region. After this other melanophores appeared over the body and on the yolk.

The melanophores on the embryo and on the yolk were normally in the stellate condition. The response of the melanophores on embryos up to the hatching stage when subjected to various backgrounds was not sufficiently consistent for the writer to arrive at any definite conclusion as to their co-ordination. These melanophores, however, contracted immediately in response to mechanical stimuli. They contracted uniformly also when the young were subjected to low temperatures. The melanophores in young at the hatching stage did not respond similarly over the entire body in response to cold temperature and to mechanical stimulus. By applying pressure on the head region of the young before the eyes developed these organs were prevented from developing. Using this method of eliminating the eyes and also studying melanophore reaction before eyes develop provides a method of attacking the melanophore response problem in fishes without dealing with the eye factor. It was observed that the melanophores in developing embryos without eyes were usually more expanded than those in embryos with eyes. More experimentation is necessary before any definite conclusions can be drawn as to the coordination of melanophores in the embryos of *Pomacentrus*.

STUDIES OF MANGROVE AND STRAND FLORA

JOHN H. DAVIS, JR.

Besides continuing the investigation of the dispersal, survival, and growth of the mangroves, particularly *Rhizophora mangle*, certain studies of the changes of the strand flora and some analyses of the soils of these islands were begun.

Rhizophora seedlings marked with different color paints were cast overboard at four different locations on two trips out from Key West. A significant number of these seedlings were recovered washed ashore on the east side of Loggerhead Key, giving definite data as to the direction and rate of dispersal. Two groups of seedlings had travelled 18 and 9 miles at the rates of 0.38 and 0.17 mile an hour respectively. The prevailing easterly winds and the tide flows probably account for this relatively definite and rapid dispersion. A few water and air current measurements were made to throw some light on these molar factors. Although a few thousand seedlings were cast overboard at 30 and 40 miles, they were not enough, or were not broadly enough distributed, to float into the Tortugas atoll and be recovered. Collections of other seedlings that normally reach these islands were continued. All these data seem to show that mangroves are able to migrate great distances and rather rapidly, and along fairly definite routes.

Over 4400 *Rhizophora* seedlings were planted on the intertide zone about Long Key (formerly mistakenly called Bush Key). It is hoped that a typical red mangrove community will develop from this planting. The good survival and rapid growth of seedlings planted in 1937 indicates that most of these will survive. The purpose of these plantings, and probably future ones, is to see if a mangrove swamp can be started dense enough to hold the

present loose coral fragments and calcareous sands, collect more materials about their roots, and thus build up the reef.

Comparisons of the present flora and the sizes and shapes of the islands with descriptions by Bowman¹ and Millspaugh² show that there have been some marked progressive changes on Bush Key and to a less extent on Loggerhead Key. Some preliminary maps were made to indicate these changes.

A series of soil studies were begun but results to date are too few for presentation. The studies of soil salinities show some definite correlations with the types of plant communities. Further studies of the soils should prove profitable as soil changes accompanying vegetational changes seem evident and significant.

REACTIONS TO LIGHT AND THE PHOTORECEPTORS IN THE SPINY LOBSTER, *PANULIRUS ARGUS*

WALTER N. HESS

In common with certain other decapod crustaceans, spiny lobsters from which the eyes have been removed are sensitive to light. For any given light intensity, photosensitivity in these animals varies with (a) age of animal, (b) region of body stimulated, (c) amount of pigmentation, (d) degree of dark adaptation, (e) general physiological condition of the animal.

Although the dorsal and lateral regions of the abdomen are more sensitive to light than those of the cephalothorax, the degree of photosensitivity in these regions varies, in general, inversely with the amount of pigment in the external skeleton. Mature animals with hard external skeletons are usually sensitive to light only in the regions containing very little or no pigment, but freshly molted animals are sensitive to light in other regions, including the antennæ, swimmerets, telson, uropods, and the dorsal and lateral regions of the cephalothorax and abdomen. The degree of photosensitivity is greatest in young animals and in those that have recently molted. The latter have very little pigment in their external skeletons.

Similar results were obtained in a study of *Crangon armillatus*. The freshly molted lobster, *Homarus americanus*, is also sensitive to light in many regions of its body.

A study is being made of the neuro-sensory structures in the photosensitive and non-photosensitive regions of these animals.

HABITS OF THE BASKET STAR (*GORGONOCEPHALUS AGASSIZI*)

WALTER N. HESS AND LEONARD B. CLARK

Observations on the basket star at Tortugas show that it is strictly nocturnal. In the evening these animals migrate to the top of coral ledges or, as is more usual, up the sides of sea fans. Here they spread their branching

¹H. H. M. Bowman, Botanical Ecology of the Dry Tortugas. Carnegie Inst. Wash. Pub. No. 252, pp. 109-138 (1918).

²C. F. Millspaugh, Flora of the Sand Keys of Florida. Field Columbian Mus. Pub. No. 118, Bot. Ser. 11, No. 5 (1907).

arms, which serve as a net for capturing food. As daylight approaches they withdraw their arms and retreat to shaded regions.

These animals can best be collected at night by the use of flashlights or submerged lamps. If nets are used, the animals are usually injured in removing them from their attachment, but if the sea fans to which they are attached are also taken they can be collected uninjured.

Contrary to the general impression, basket stars are quite common on coral reefs especially where sea fans occur.

STUDIES ON TUMORS IN COLD-BLOODED VERTEBRATES

BALDUIN LUCKÉ

The comparative study of neoplastic growths has in the past dealt chiefly with tumors in mammals and birds, neglecting the more primitive cold-blooded vertebrates. This restriction has been due largely to the belief that among amphibians, reptiles, and fish, neoplasms are rare and difficult to obtain for study. Information concerning tumors in these classes has been based upon chance observations, rather than upon systematic investigations of particular kinds of tumors in certain species. It seems not unlikely, however, that such study would add much to our knowledge concerning the nature of neoplastic growths in general.

The aim of the present work was to investigate the occurrence, distribution, and nature of tumors among the fish and turtles available in the waters around the Dry Tortugas. The search has yielded much additional information about tumors of nerves in fish of the snapper family (the first account of which was given in last year's report); in addition, two new varieties of tumors were found, one in the green turtle, another in the slippery dick, a small reef fish. These several kinds of tumors are common and occur in easily available species, and all of them appear to be suitable for a more detailed experimental investigation.

Nerve sheath tumors (neurilemmoma, neurofibroma, schwannoma) in fish of the snapper family (Lutianidæ). This investigation is a continuation of the study reported in the Year Book for 1936-1937. The total number of tumors which have been obtained to the present is 76. This relatively large number permits a more precise analysis of the anatomical distribution and habits of the growths. It is found that most of the tumors are situated along the course of the larger subcutaneous nerves, particularly those of the head and the dorsal regions. Their peculiar distribution, together with their characteristic histological appearance, now makes it very probable that these growths have their origin in the sheath of the nerves. They bear a striking similarity to tumors of the nerve sheath in man. Like them they form two main types, in one of which the component cells are oriented in such a manner as to form rows or so-called palisades; the other type has a very loose edematous structure, and no particular arrangement of its component cells is demonstrable. It is estimated that approximately 1 per cent of gray snappers (*Lutianus griseus*) are affected with this neoplasm; the incidence in the other varieties of snappers is not known.

Transplantation experiments were made using a technique which had proved successful with an amphibian tumor studied by the writer. Small fragments were inoculated by means of a hollow needle into the anterior chamber or the vitreous of the eyes of a number of snappers. After from 8 to 10 weeks the inoculated fish were killed and the eyes excised and prepared for histological examination. The results of these transplantation experiments will be reported on completion of the study.

Multiple papillomas of the skin and the eye in the green turtle (Chelonia mydas). The newgrowths which have been observed in reptiles are even more limited in number than is the case in amphibians and fish. Hence it is of particular interest to record that green turtles not infrequently suffer from papillomatous neoplasms which may attain so great a size as seriously to interfere with their locomotion.

The tumors occurred in a large female green turtle caught off Cape Sable. They were located on the edges of both anterior flippers, in the axillary regions, the neck, on the eyelids, the corneal surfaces, and on the tail. In shape they were hemispherical or globular, and had rough, warty surfaces covered with dry, coarse, cornified epiderm, which in some areas was superficially ulcerated. Some of the tumors were sessile, others had a broad pedunculated base. In some areas, particularly in the axillary regions, several were crowded together, elsewhere they were solitary. In size, the individual tumors ranged from small warts a few millimeters in greatest diameter to large masses nearly 5 cm. in diameter. All were of tough consistency, and had a dense white fibrous, bloodless cut surface.

Histologically, the neoplasms are typical papillomas, consisting of a fibrous core covered with many layers of epiderm the surface of which has undergone extensive keratinization. All stages of the papillomatous growth are represented in the animal; the smaller show a relative preponderance of epithelial over mesodermal components; as the tumors increase in size the fibrous components become more prominent, in the largest growths they greatly predominate. Richly cellular areas, frequently encountered, indicate that the fibrous portions of the tumors are actively proliferating.

The papillomas of the turtle correspond very closely to epidermal papillomas of man and other mammals. Several of these have been shown to be caused by viruses. It would be of great interest if a similar etiologic factor could be demonstrated in these papillomas of a very different group of animals.

Epithelial growths of the skin in the slippery dick (Halichæres radiatus). There is no sharp dividing line between "true" neoplasms and certain exaggerated growths due to irritations of one kind or other. Indeed many of the latter have been found to merge by ill-defined stages with the former. Their study is the more indicated because the transition stages may furnish information as to the nature of neoplastic growths in general. A tumorous condition which seems to belong in this border-line group occurs as a rather common disease in the little reef fish, slippery dick. Thirty examples were observed among approximately 6000 of these fish. The tumors generally are circumscribed, flat, somewhat nodular elevations of the skin tending to undergo ulceration. They have a grayish, dull appearance and a soft con-

sistency. The scales in affected areas are elevated or have apparently been destroyed entirely. The disease is distributed over many parts of the surface, but is most commonly encountered in the caudal region; destruction of fins is common. The growths often attain very large size. Histologically they are composed of masses of epidermal cells, arranged in alveolar groupings; stroma and vessels are scanty. The corium is infiltrated but no extension into the subjacent musculature is observed in the present series. In many tumors striking cytological changes have taken place; the cytoplasm is ballooned and partly occupied by a small deep staining chromatic body surrounded by faintly acidophilic material; the nature of these inclusions is still a matter of uncertainty.

Fish affected with these tumors can readily be kept in indoor aquaria. They should prove excellent material for the experimental investigation of this disease.

FURTHER STUDIES ON THE ELECTRICAL BEHAVIOR OF *VALONIA VENTRICOSA*

GORDON MARSH

By means of a rotating sector disk giving two equal light-dark periods per revolution, intermittent and continuous light were compared in their effect upon the inherent E.M.F. of *Valonia*. At frequencies of about 8 to 10 per second and intensities up to 1600 foot-candles no consistent difference was found, the effect of intermittent light approximating that of continuous light of half the intensity.

The effect of KCN upon the potential was determined over the range of concentrations from 2×10^{-8} M to 5×10^{-3} both in light and in darkness. The cyanide was dissolved in sea water and the latter restored to its original pH with HCl, using thymol blue as indicator. When the steady potential in the presence of cyanide is plotted against concentration, a curve results which drops rapidly to around 1×10^{-4} M and but slightly more for higher concentrations. All depressions in potential were reversible during the time limits involved. Recovery of the original potential upon removal to sea was slower the higher the concentration of cyanide used. In the dark the maximum depression obtained varied from 40 to 75 per cent. In the light the depression was much greater both as a percentage and as an absolute figure; the potential level in high concentration of KCN was approximately the same in light as in darkness. This is consistent with the known effects of cyanide, which normally depresses respiration reversibly to the above amounts for many materials and at high concentrations completely inhibits photosynthesis. NaCN yielded substantially the same results as KCN.

A similar study was made with ether between the concentrations 0.01 and 2.5 per cent by volume. The curve of potential *vs.* concentration resembles roughly that obtained with cyanide. Reversible depression of the potential was obtained with concentrations up to 1.0 per cent; 1.5 per cent and higher coagulated the protoplast. The individual variability of behavior of the cells was high, as is typical of the effect of ether. Concentrations between 0.5 and 0.1 per cent produced a preliminary increase in potential which in extreme cases reached eight times the value of the potential in sea water

for cells in the dark and three times the value for cells exposed to light, and required about three hours to descend to a steady level.

A preliminary survey of the influence of the pH of the surrounding sea water on the protoplasmic potential difference was made, using sulfonphthalein indicators. The potential increased with pH 4—11, the effect of equal pH steps being less near the pH of sea water. Differences were observed between the effects of KOH and NaOH and between the effects of illumination at low and at high pH's.

THE RESPONSE OF ASCIDIAN LARVÆ TOWARD CERTAIN HORMONES

PAUL A. NICOLL

The immediate stimulus of ascidian metamorphosis, regardless of the ultimate cause, may be regarded as a state of condition incompatible with continuance of larval life. The subsequent differentiation, development, and growth of the primitive cells from which the adult organism arises follows this breakdown of the larval action system more or less rapidly depending on the species under consideration. Grave and Nicoll (in press) have suggested several paths by which this condition could be reached. This summer a start was made in the study of possible factors which would prevent the development of this state of condition that terminates larval existence and so permit the more highly organized prochordate type of individual to survive.

The possibility of a deficiency or complete lack of some hormone essential for completion and survival of the prochordate animal was investigated. Using the same technical procedures described by Grave, larvæ of *Ascidia nigra* were subjected to various concentrations of theelin, theelol, adrenalin, thyroxine, and testosterone, as well as a cortical extract of proved potency for survival of adrenalectomized dogs. The first three hormones were supplied through the kindness of Parke, Davis and Company. Of these only theelol and adrenalin had any influence on the larvæ, which in both cases amounted to lengthening the larval life period but without allowing any development of a digestive or circulatory system, which would seem to be necessary if the prochordate type were to have a separate existence. Technical difficulties prevented adequate tests with testosterone but the failure of crystalline thyroxine to influence metamorphosis in either direction was definite.

In addition to the hormone experiments the larvæ were treated with two crystalline vitamins, vitamin C and vitamin B₁, on the theory that possible deficiencies of basic food essentials might lead to the breakdown of the larval action system. However, neither of the vitamins, using a wide range of concentrations in both cases, was found to influence in any way the length of larval life.

Besides the experimental work considerable time was devoted to the collection and study of various species of ascidians that may be found in the waters near the Tortugas Laboratory. Two regions previously uninvestigated which proved rich in ascidians of all species were located on the east sides of Sand and East Keys.

Of the many species collected, some of which will undoubtedly prove to be undescribed when thoroughly studied, one may be mentioned at this time.

It is a member of the genus *Ascidia* and appears more closely related to *Ascidia hygomiana* than to others of the group. It differs markedly from other species of the genus in three important aspects: (1) The dorsal tubercle is much larger and though heart-shaped is very decidedly convoluted even in young specimens. (2) The eggs are two to three times the size of the other species of *Ascidia* found in the region, and the outer test cells are deeply pigmented, giving the eggs a brownish color in place of the milk-white color found in other species. (3) The adults, which range in size up to 90 by 35 mm. and are quite thick owing to a large mud sack, have a thin test that is almost colorless. They may range in color, however, from brilliant red through orange-brown to gray or colorless owing to pigment in the mantle cells. Although insufficiently studied at this time to insure its acceptance as a new species, it has been given the tentative name of *Ascidia gardenensis*. The name is derived from Garden Key, where the first individuals were collected, though later specimens were found at East Key.

STUDIES ON THE DEVELOPMENT OF *PTYCHODERA BAHAMENSIS*

FERNANDUS PAYNE

Three things were attempted during the summer of 1938. *Ptychodera bahamensis* is supposedly a protochordate. If so, what would be the effects of the anterior pituitary hormones on the development and discharge of the sex cells? Without giving details of the experiments, the answer is that no effects were observed. Five years earlier when fertilization and larval development were studied, transformation was not obtained. A second attempt was made the past summer, but for some unknown reason the larvæ after a week or ten days remain about stationary. With the idea that thyroxine might hasten transformation, larvæ were subjected to a sea-water solution of thyroxine (1 g. to 1000 cc.) for 24 hours. No effects were noticeable. It was not even toxic, while whole thyroid solutions were toxic. Larvæ lived in the laboratory for 25 days. No larvæ were taken in the tow although such collections were examined every day for five weeks. The sand in the immediate vicinity of the adult forms was examined carefully with the eye and also with the aid of a low-power binocular microscope, but no recently transformed individuals were found. The smallest specimens discovered were about 1 inch in length. Six weeks seem too short a period to unravel this story.

For some time the writer has been interested in the cytology of secretion, and since the body wall of *Ptychodera* contains many large and different kinds of secretory cells, material was collected for later study.

On July 24, *Amphioxus* larvæ were discovered in tow taken on the west side of the island between the lighthouse and the south end. Continued daily observations were made up to and including August 4. Larvæ were present each day during this period. Adults, of course, are present somewhere in this vicinity, and if they can be discovered will prove useful material for further investigations. Many of the larvæ were fixed for cytological studies.

INVESTIGATIONS ON ASCIDIANS

HAROLD H. PLOUGH AND NORRIS JONES

The entire season was devoted to the study of the structure, development, budding, and colony formation of *Ecteinascidia tortugensis* sp. nov. mentioned in our previous reports in Year Books for 1935-1936 and 1936-1937. The stolons of this species have been used in all our composite colonies and chimæras with *E. conklini* and *Perophora*, so that it seemed desirable that a complete morphological description of this species should be available previous to any account of the experimentally produced specimens. As soon as a few final drawings are added to the plates this account will be ready for publication, for the study is now in manuscript.

During the 1938 season *E. tortugensis* was one of the commonest ascidians at the Tortugas. That it has not been studied before seems to be due to its rather small size (5 to 6 mm.) and its relatively inaccessible habitat. It was found occasionally on the under sides of rocks under the coal wharf at Garden Key, but during late July and early August it occurred in large numbers on the under sides of rocks just below low-water mark on the outside of both Bush Key and Long Key. Later it was found in similar situations on Bird Key Bank and (by Dr. Nicoll) at East Key. It appears to prefer these exposed locations where there is constant wave action and consequently pure, relatively cool water.

One or two morphological facts are worthy of note here: (1) The oviduct in *Ecteinascidia* was observed first by Berrill¹ (*E. turbinata* and *E. conklini*). It was found in *E. tortugensis* in the same situation, namely a short wide straight tube, through which eggs pass directly from the ovary to the posterior (aboral) end of the right atrial cavity. The latter is the brood pouch in which the eggs develop to the larval stage. (2) Soon after the tadpole larva is expelled from the atrial siphon, the stigmata become visible though not yet functional. Four rows of stigmata are clearly present at this stage, and this observation has been confirmed by examination on mounted specimens. Since this does not agree with Berrill's² account of *E. conklini*, we examined larvæ of the latter. In these too, four rows are clearly visible in the earliest stages. Thus these *Ecteinascidia* correspond more closely than Berrill supposed to the larvæ of Ascidiidæ and Styelidæ. (3) *E. tortugensis* is always closely attached to the rock by the test along its ventral side below the endostyle. In this it is quite unlike the other *Ecteinascidia* and *Perophora*, which are attached by stolons at the posterior end. In this mode of attachment it closely resembles many of the solitary species of *Ascidia*.

The relationships of the family Perophoridae (to which *Perophora* and *Ecteinascidia* belong) are still in question. Van Name³ has included them with the Ascidiidæ, while Berrill⁴ considers that they are distinct and offers

¹ N. J. Berrill, *Ascidians of the Bermudas*. Biol. Bull., vol. 62 (1932).

² N. J. Berrill, *Studies in tunicate development III*. Phil. Trans. Roy. Soc. London, ser. B, No. 226 (1935).

³ W. G. Van Name, *Ascidians of the West Indian region*. Bull. Amer. Mus. Nat. Hist. No. 44 (1921).

⁴ N. J. Berrill, *Studies in tunicate development V*. Phil. Trans. Roy. Soc. London, ser. B, No. 530 (1936).

several suggestions as to their derivation. In general the study of this new species appears to lend weight to one of Berrill's three alternatives,⁵ that they represent "an early step in the change from a cionid to an ascidiid type."

STUDY OF THE PLANKTON IN TROPICAL WATERS

GORDON A. RILEY

The small quantity of plankton in tropical waters, as contrasted with that in higher latitudes, provides an interesting study of the differential effect of environmental factors. The work reported here is intended as a preliminary survey of the problems involved. In the final report a study of Long Island Sound will be included for comparison.

The mean quantity of chlorophyll and total plant pigments in fifteen series of samples was found to be approximately one twenty-fifth the amount in Long Island Sound. The plant pigments in the net plankton averaged 1 per cent of spring bloom conditions in the Plymouth Sound region, described by Harvey, Cooper, Lebour, and Russell in 1935. The ratio of plants to animals is about the same in both regions.

The amount of soluble phosphate was small, averaging 1.3 mg. of P per m³. Analyses of nitrate were not made, but experiments show that it, rather than phosphate or iron, is the most important limiting factor.

In order to estimate productivity, light and dark bottles containing ordinary sea water were suspended at various depths and after a period of five to seven days were analyzed for oxygen and occasionally for chlorophyll and P. The oxygen production averaged 0.96 mg. per liter per week at a depth of 1 m. This is one-third to one-half the amount produced in Long Island Sound. It would therefore appear that the actual productivity is much greater than the standing crop would indicate. This tends to support the theoretical considerations discussed by Harvey and his associates in 1935. It should be added, however, that the photosynthetic rate is not an absolute index of productivity. The values obtained at these high temperatures (27.5 to 29.0° C.) must be discounted by experimental means in order to allow for the higher metabolic rate. Until then, an accurate comparison cannot be made.

The productivity equation is

$$W = 2.18x + 0.75y - 0.00035z - 0.09$$

where W is oxygen production in grams per m³ per week, x is chlorophyll in milligrams per m³, y is P in milligrams per m³, and z is the number of animals per m³. The correlation between calculated and actual values for oxygen production is 0.706. According to the equation, animal consumption is an important factor, causing 35 per cent of the variations in oxygen production. Contrary to the experimental evidence, phosphate appears to be responsible for 38 per cent of the variations. It is possible, however, that the constant is weighted by a direct relationship between variations of nitrate and phosphate.

⁵ *Ibid.*, p. 60.

REGENERATION IN THE STARFISH *LINCKIA* AND IN THE PROTOZOAN
CONDYLOSTOMA

VANCE TARTAR

Regeneration in the starfish Linckia. The starfish *Linckia* is remarkable in being able to regenerate the whole animal from a single isolated arm without any part of the original disc. It was proposed to find out what regeneration would occur in isolated arms having a cut surface at each end, in the hope of identifying the factors which determine whether a disc or an arm tip will be formed at a cut surface. Arms of *Linckia* were cut off near their bases and the tips likewise removed so that the fragments had a cut surface at each end. Since the arm tapers very little, the two wound areas were approximately equal in size. In order to distinguish the proximal from the distal end, the latter was always cut at an angle to the axis of the arm, a procedure which tended to equalize the area of the two cut surfaces. Regeneration at both ends of such fragments was compared with that of isolated arms having only one cut surface and with that of discs from which the arms had been removed. A total of 142 isolated arms, together with 46 discs, comprised the material for this study. The results of the study are as follows:

1. Regeneration was most rapid in armless discs, and slowest in whole stars with only one or two arm tips removed.

2. In five cases regeneration at the cut surfaces on the original disc was more rapid than that on the proximal (same level) cut surface of arms isolated from that disc. In only one case was this relationship reversed, with a slightly more rapid regeneration in the isolated arms.

3. Seventeen armless discs showed equal regeneration on all cut surfaces, while in twelve cases the regeneration was not uniform.

4. The rate of regeneration in isolated arms is, within wide limits, not correlated with the size of the fragment.

5. There was no demonstrable difference in the rate of regeneration in isolated arms having one, as compared with those having two cut surfaces.

The above two facts suggest that the materials for regeneration are supplied only by the tissues adjacent to the cut surface.

6. When the fragments are sorted into three size groups, an interesting relationship is shown. Of 15 large isolated arms of length 64–48 mm., 3 regenerated into 5-armed starfish, and 12 into 6-armed stars. Of 35 medium-sized fragments of length 45–31 mm., 3 regenerated into 4-armed, 19 into 5-armed, and 13 into 6-armed starfish. Of 26 small fragments of length 29–14 mm., one regenerated into a 4-armed, 21 into 5-armed, and 4 into 6-armed stars. It is suggested that the number of arms differentiated from the blastema depends to some extent upon the size of the fragment, the smaller fragments tending to have fewer arms than the larger. A sample of 60 starfish collected at random consisted of 33 stars with 5 arms, 26 with 6 arms, and one with 7 arms.

7. Under normal conditions polarity is maintained in the isolated arm, that is, the proximal end regenerates the disc and the distal end an arm tip.

8. Regeneration at the proximal cut end of an isolated arm was generally more rapid than at the distal cut end. Twenty-three cases showed more rapid regeneration proximally than distally, and in only six cases did the regeneration appear to be approximately equal at both ends. The remaining fragments showed no regeneration at the end of one month.

9. In one isolated arm regeneration failed to occur at the proximal cut surface, but an arm tip was formed at the distal surface.

These data clearly show that under normal circumstances the polarity of arms is not altered by isolation, but a remarkable specimen of *Linckia* found by Dr. H. H. Darby at Tortugas some years ago suggests that under certain conditions loss of polarity may occur. This was a double animal which had two small discs of slightly unequal size connected by a large arm. The most reasonable explanation of the origin of this animal is that it was formed by an isolated arm which regenerated a disc at *both* ends.

Specimens of the starfish were preserved for species identification. The writer takes pleasure in expressing his indebtedness to Dr. Hugh H. Darby for his interest in this problem and for his helpful suggestions during the course of the work.

Regeneration in the ciliate Condyllostoma. In the large brackish-water ciliate *Condyllostoma* (probably *magnum*) the macronucleus is clearly visible in the living organism as a string of nuclear beads, all contained within the same membrane, which extends along the right side of the elongate cell. The distribution of the macronucleus in the trophic stage is such that if the cell is cut in two longitudinally, the right half (which will be referred to as the A-fragment) contains two to three times as many nuclear segments as the left half (B-fragment), in which their number is usually 5 or 6. Apart from this difference in quantity of nuclear material the two halves were equivalent, each being of the same shape and size, and containing equal portions of the cytoplasmic differentiations of the original cell. It appeared therefore that this protozoan offers the peculiar opportunity of obtaining two half-fragments which are equivalent in all respects except that one contains two to three times as much nuclear material as the other; and it was proposed to follow the fate of these fragments to determine the influence of the amount of nuclear material on the rate of regeneration.

For the purpose of the present problem it was necessary that the two fragments to be compared both lived, regenerated, were of equal size, and maintained the elongate shape after cutting. Out of over 100 sets of such fragments, only 10 fulfilled all these requirements, and these 20 fragments form the material from which the following results were obtained.

1. In one case the two fragments regenerated in the same time, while in all other cases the fragment containing more nuclear material regenerated more rapidly than its partner with less nuclear substance. The average time for regeneration of A-fragments was 20.3 hours, while B-fragments required 41.2 hours.

2. It is not to be concluded, however, that the differentiation process itself proceeded at different rates in the two series; for when the time for regeneration is measured, not from the instant of cutting, but from the time of the

first appearance of the anlagen of the cell differentiations, the two series are approximately equal. The average time for the visible differentiation process in A-fragments was 18.0 hours, as compared with 18.9 hours for B-fragments.

3. The condition of the macronucleus in 8 of the 10 B-fragments was determined at the time of completion of regeneration. These fragments had all regenerated the nucleus, i.e., instead of only 5 or 6 nuclear segments located in the anterior end as at the time of cutting, there was a long chain nucleus extending the length of the cell.

It may be suggested simply as a tentative hypothesis that the additional time required for most of the fragments with fewer nuclei to regenerate was due, not to a retardation of the differentiation process itself, but rather to growth of the nucleus which is necessary before the cytoplasmic regeneration can begin.

As stated above, it was rarely that the longitudinal half-fragments with only 5 to 6 nuclear segments remained elongate, and in this respect they differed markedly from the companion fragments with two to three times as much nuclear material. Thus it was common for the fragments to contract into a modified spherical form, from which they seldom recovered. Of 66 A-fragments in the trophic stage, 60 remained elongate, while only 6 contracted into a ball. These halves are to be compared with 54 B-fragments, also in the trophic stage, of which only 15 remained elongate, while 39 assumed the spherical shape. Thus a diminution of the amount of nuclear material favors the assumption of a form with minimum surface.

In division the protozoan elongates by stretching, the cytoplasm becomes darker and more granular, the macronucleus contracts into a short rod located near the mid-point of the cell, and the anlagen of the new pharynges of the daughter cells appear, one at the anterior end, and the other at the middle of the cell. Two such dividing *Condyllostoma* were cut transversely so that in one case the macronucleus remained entirely within the anterior daughter cell, while in the other the nucleus was confined to the posterior partner. (The fate of the micronuclei was undetermined, though it is probable that they remained closely associated with the macronucleus.) In both cases the cytoplasmic differentiation stopped immediately in the enucleate cell, but went to completion in the nucleate half. Thus the presence of the macronucleus is apparently required throughout the process of differentiation.

In two cases the cells were split longitudinally, but the two equal halves remained connected by their posterior ends. Such cells stretched out into elongate bands of which the half with the greater number of nuclear beads formed the functional anterior end. Regeneration of the couplet was accomplished by division. The anlage for the pharynx of the anterior daughter appeared at the anterior end of the A-fragment, while that of the B-fragment appeared at the point of connection, i.e., at its *posterior* extremity. Thus the polarity of the B-fragments became completely reversed.

Several hundred normal *Condyllostoma* from the stock culture were examined and none of these departed from the following description: On the ventral side at the anterior end is the large groove-like pharynx, having a prominent membranelle and mouth on the right side and a row of large ciliary

plates on the left. In contrast to this uniformity, the regeneration of fragments frequently produced atypical forms of great variety. Abnormality was most frequent in B-fragments, which began with a very low nucleoplasmic ratio. The distribution of abnormal forms was as follows:

Of 66 A-fragments, 60 were normal and only 6 abnormal.

Of 47 B-fragments, only 9 were normal, while 38 were abnormal. These classes contain the following subclasses, which indicate that abnormality of the regeneration was not necessarily connected with the irregular (spherical) shape which the fragments so frequently assumed.

Of 6 spherical A-fragments, all were normal.

Of 60 elongate A-fragments, 6 were abnormal.

Of 34 spherical B-fragments, 29 were abnormal.

Of 13 elongate B-fragments, 9 were abnormal.

Space does not permit a complete description of all abnormalities encountered, but several types may be enumerated: (1) reversed pharynx, producing an animal which was the mirror image of the normal (7 cases); (2) circular pharynx, in which the membranelle and the row of ciliary plates formed more or less complete concentric rings (32 cases); (3) double pharynx, several types (13 cases); (4) double animal, having two pharynges and two "tails" oppositely directed (1 case); (5) heteromorph, having a pharynx at each end of the cell (2 cases); (6) pharynx open at each end (2 cases).

During the life of such abnormal cells there occurred frequent dedifferentiation and redifferentiation so that the pharynx changed from one form to another or even attained the normal form in some cases. It was demonstrated, therefore, that in regeneration of *Condyllostoma* the normal form and typical arrangement of cytoplasmic differentiations may easily be altered.

THE EFFECT OF INTENSITY OF LIGHT ON PHOTODYNAMIC REACTIONS

D. H. TENNENT

This work was in continuation of that reported in Year Books Nos. 34, 35, and 36. A General Electric exposure meter, with calibrated filters, was used to determine the intensity of sunlight, or of artificial light, used in irradiating *Lytechinus* eggs in solutions of dye in sea water.

Each lot of eggs was divided into portions and the different portions irradiated with light of full intensity or, by the introduction of calibrated filters between the source of illumination and the eggs, with light of reduced intensity. Opal glass plates, Whatman's filter paper no. 50, and various Corning glass filters were used in reducing the intensity and changing the quality of light reaching the eggs. The greater part of the work was done with Greubler's neutral red in 1:150,000 sea-water solution, and a smaller amount with National Aniline Company's brilliant cresyl blue and Coleman and Bell's brilliant green.

In the experiments performed, uninseminated *Lytechinus* eggs in 1:150,000 solution of neutral red in sea water were irradiated with sunlight or with artificial light at intensities varying from 25 to about 14,000 foot-candles. After irradiation the eggs were inseminated and studied carefully under the

microscope for surface changes, formation of fertilization membrane, cleavage, etc.

The analyses of the data completed at the present time indicate that the threshold for violent surface reaction (blister cytolysis) of *Lytechinus* eggs in neutral red sea water lies at about 2500 foot-candles. At an intensity of 250 foot-candles the eggs did not blister and cleavage did not go beyond the 8-cell stage; at 500 foot-candles there was no blistering and little normal cleavage; at 2100 foot-candles, no blistering and no normal cleavage beyond the 8-cell stage. At intensities from 3000 up to 14,000 foot-candles there was a regular increase in the violence of the surface reaction and complete inhibition of the cleavage processes.

GEOPHYSICAL LABORATORY¹

L. H. ADAMS, DIRECTOR

To the geologist differentiation means the process by which a molten silicate mass produces rocks of different kinds. But the term differentiation has a far wider significance, and properly may be applied to any change from a simple state to a complex one. Opposed to differentiation is assimilation, which means the incorporation of one rock mass by another, or, more generally, a change in the direction of uniformity or simplicity. We recognize differentiation and assimilation as the agents that, operating throughout all geologic time, have caused the Earth to attain its present condition. Indeed all changes in the physical world may be thought of as consequences of these two processes. It is instructive also to regard differentiation merely as a decrease of entropy, and assimilation an increase in the same somewhat mysterious quantity, which is used in exact statement concerning change because it allows us to describe change in terms of definite and unambiguous units.

Perhaps the greatest generalization in the physical sciences states that the entropy always tends to increase in the course of any spontaneous process unless special forces or restraints are imposed on the system under consideration. The famous generalization teaches us that the natural and universal tendency is assimilation. Left to themselves, all aggregations of matter tend to become uniform throughout; the ultimate state, if no hitherto undiscovered factors intervene, is one of complete homogeneity. Diffusion, a manifestation of the ceaseless motion of atoms and molecules, would in time reduce the Earth and the whole universe to a state in which the composition of any cubic centimeter of space would be exactly the same as that of every other cubic centimeter.

The significant fact is that the primary tendency for all aggregations of matter is a degradation of form, of energy, or of composition. Mountain masses are reduced to peneplanes, thermal energy becomes unavailable for useful work, and mixtures become homogeneous in composition and texture. But although the tendency is ever toward the state in which individuality is destroyed, there are intermediate stages in which the natural and usual course of events reverses itself; we have alternate cycles of the twin effects that, depending on the factors to be emphasized, may be designated as mixing and unmixing, planation and upheaval, diffusion and segregation, destruction and creation, decay and growth, or assimilation and differentiation—different names for the one set of fundamental opposing tendencies.

Viewed in a broad way, the problems of geophysics are largely those of differentiation. Whether all or a part of the Earth was once uniform in composition, it is now decidedly heterogeneous, and differentiation is responsible for those aspects of its geologic history that are the most interesting and also the most puzzling. It is easy to understand how materials can mix to form a solution, but it is difficult to acquire adequate knowledge concerning the mechanism by which they can unmix. A land surface by well-known processes is reduced to a level plane, and subsequently by forces that are not yet well understood is uplifted to great heights. There is a general tendency

¹ Situated in Washington, District of Columbia.

to reduce the state of all things to a dead level, and the consequences of this tendency are simple. The reverse effect of building up structures and differences in composition is complex and often appears to defy explanation. In many instances we can predict the course of processes by which structures are torn down but not the manner in which they may be built up again.

That part of the Earth's crust amenable to direct or indirect observation offers a fascinating series of problems, which in common with all problems present a challenge to the inquiring mind. In accepting the challenge we resort to laboratory experimentation and in effect presume to imitate Nature on a small scale. At the Geophysical Laboratory our attack has proceeded in three principal directions: (1) By crystallization or by other means, we induce the separation of mixtures into their constituents (solid, liquid, and gaseous) and define the conditions necessary for the appearance of the individual phases; (2) we search for mechanical processes that will sort, transport, and arrange the products, and (3) we study the structure of solids and liquids, utilizing the most powerful devices of modern physics, in order to predict the behavior of mixtures subjected to varying environment.

During the past year important progress has been made in each of these major lines of attack. A lengthy investigation of the volatile constituents of natural rocks and a comparison with the gases that, emanating from volcanoes often in tremendous volume, contribute to their awe-inspiring eruptions has established striking similarities in composition and has thrown light on the properties of lavas, on the phenomenon of volcanism, and on the mechanism of flowage in masses of molten silicates. Studies of the incrustations from volcanoes and fumaroles have shown the presence of a surprising number of the less familiar elements and have suggested that the deposition of these elements in considerable amount by volatile transport is an important factor in one variety of differentiation, the formation of ore deposits. Closely related to the work of the Geophysical Laboratory, and in effect a part of its program, is the thorough investigation of volcanic phenomena at Montserrat carried out by F. A. Perret, a Research Associate of the Institution. The results of a study extending over a period of four years have been assembled for publication as a companion volume to the previous memoirs on Vesuvius and on Mont Pelée by the same investigator.

Several systems containing water as an active ingredient have been successfully investigated. Among these are: boron oxide and water, which shows up some of the conditions under which difficultly crystallizable substances make their appearance; calcium sulfate and water, which has cleared up some puzzling questions concerning the formation of gypsum deposits; and sodium hydroxide and water, the study of which marks the first step in one program for the thorough investigations of silicate systems at moderate temperatures and pressures—a program made feasible through financial aid by the Carnegie Corporation of New York and having as its objective the acquiring of knowledge concerning the formation of pegmatites and the hydrothermal alteration of minerals. In a systematic study of the constitution of samples of the ocean floor collected by the *Carnegie* numerous minerals have been identified and found to include dolomite, which obviously was deposited directly from the sea water. Further studies of the constitu-

ents of deep-sea samples will be greatly facilitated by the portable winch which has been constructed and made ready for collecting cores from the bottom of the oceans at their greatest depths.

Directly applicable to many great problems of differentiation are the results of recently completed investigations on the melting behavior of various combinations of rock-forming oxides; somewhat less directly applicable but quite essential are other researches of the past year, notably the study of the properties of solutions under pressure and the measurement of latent heats of fusion by a rapid and convenient method.

The principal features of recent and current investigations at the Geophysical Laboratory may be summarized as follows.

THE VOLATILE CONSTITUENTS OF MAGMAS

Gases in rocks. In the course of our first investigations of volcanoes it became evident that further information concerning the nature and composition of volcanic gases was essential. The study of these gases naturally led to an investigation of the small but significant amounts of gases that are found in practically all types of rocks. By suitable treatment, such as heating the rock samples under reduced pressure, the gases can be extracted from the rocks and collected in quantities sufficient for chemical analysis. A comprehensive series of investigations [Shepherd] on the volatile constituents of lavas and various plutonic rocks has now yielded information that throws light not only upon the phenomenon of volcanism but also upon the mechanism by which some geologic formations are produced.

Results obtained for the vacuum-tube samples collected at Kilauea—the only volcano from which it has been possible to secure entirely satisfactory gas samples—demonstrated that the composition of the gas expelled from a volcano is not constant. The most outstanding characteristic is the preponderance of water, which comprises eighty per cent or more of the total volume of these gases. The lack of uniformity in the gases from Kilauea is readily explained by the nature of the volcano structure. A process of local concentration is believed to be responsible for the varying composition of not only volcano gases but also those obtained by exhausting rocks in vacuo. These processes of local concentration and re-volatilization have far-reaching significance for both volcanology and petrology.

Following the study of volcano gases the next step was the determination of the gases retained by freshly collected lavas. Comparison of these measurements with the data for vacuum-tube samples showed the composition to be sensibly identical and warranted the inference that similar studies of lavas from craters that are not suitable for direct gas-collecting should furnish useful information concerning the gases erupted at such sources. Analyses of the gases from lavas of Mont Pelée, Martinique, and of Lassen Peak, California, were made. Just as was the case for volcanic gases, the results showed that the composition is variable and that water is the dominant constituent. Fluorine appears as a more common element than had been expected, the hydrocarbons are practically absent, and the rare gases are present only in minute amounts.

Other measurements were made on a number of typical rocks, such as obsidians, granites, and diabases. Of much interest is the conclusion that the volumes of gas retained by lavas and plutonic rocks tend to cluster around a series of values that are characteristic of the rock type. Thus with lavas, about 6 cubic centimeters per gram of rock is the usual amount, for both andesitic and basaltic lavas. When exceptions occur they usually can be connected with features revealed by a careful examination of the material. Presumably the above figure is related in some way to the solubility or vapor pressure of the volatile constituents in the silicate magma, and to the temperature and pressure at the time of extrusion.

On the other hand, the volume of gases obtained from the plutonic rocks is usually about 30 cc/g. For granites this figure is in accord with what would be expected if we take account of the mica and hornblende and allow a little for adsorbed water, but it should be noted that diabase yields nearly the same amount of gas. This value, 30 cc/g, represents a minimum for these rocks, and is increased many fold by alteration that is too slight to be observed upon ordinary examination. Noticeable alteration causes an enormous increase in the quantity of gas. Alteration such as we are now considering is believed to be a consequence of local enrichment of the volatiles in the rock or magma at appropriate places in the Earth's crust.

In a series of obsidians both the water content and the vesiculation-temperature relationship were determined. These observations raise interesting questions concerning the mechanism of obsidian and rhyolitic lava flows. Small differences in the water content (tenths of a per cent) make great differences in the viscosity of such glasses, and for the very "dry" glasses it is difficult to imagine their flowing at any temperature yet observed around volcanoes. Moreover, given sufficient water to be able to flow, we should ordinarily expect much pumice or even an explosive action. Attention is called to the Mono Craters in California where the dry cores seem best explained by assuming that they were carried along by "wetter" envelopes which by explosive eruptions furnished the main mass of the structure. Because the rate of diffusion of water in these glasses shows no abnormal speed, and also because it is difficult to account for the dryness of the cores by any differentiation or cooling-down process that would leave the outer layers richer in water, we incline to the hypothesis that such masses as a whole represent reactivated material—rehydrated masses for which the process has not had time to penetrate evenly throughout the mass. This reactivation of dormant magmas may result from local enrichment in volatiles brought about by the movement of fresh magma in depth, with corresponding shifting of both volatiles and geotherms.

Attention is called to experiments which indicate that for the acid glasses and equally for the "mother-liquor" of a crystallizing magma, the loss of volatile constituents causes a very sudden change of viscosity from a relatively fluid to a very rigid state. Since the quantity of water needed to liquefy silicate mixtures at relatively low temperatures is small (at least for the more acidic magmas), it is possible that reactivation and remelting of suitably trapped masses of injected country rock are more frequent than has been supposed.

Our observations on obsidians are in complete accord with the results of other studies [Goranson] on the solubility of water, at high pressure, in magmas of rhyolitic and granitic composition. From these results and from the determinations of the water present in unaltered rocks it appears that the primitive, deep-seated magmas are not necessarily highly charged with volatile constituents and that a high content of "volatiles" is more likely to be caused by a process of local concentration and enrichment, which in volcanic regions may be a factor of especial importance.

Sublimates. Upon examining sublimates such as those that occur around volcanoes and fumaroles, or appear in the cooler parts of the laboratory apparatus used for pumping gases out of rocks, we find many elements which the chemist ordinarily regards as non-volatile. For the most part these sublimates have been formed at temperatures so high that water is more likely to behave as a gas and that chemical effects such as hydrolysis may be ruled out. At the present time we do not know sufficiently well which elements are volatile under the assumed conditions, nor in what form they may separate from a heated rock. The volatility has usually been ascribed to the formation of sulfides or halides. It is possible that in some instances hydrides are produced in the presence of reducing agents, under which conditions it is not impossible that nitrides may also be present. Although something is known concerning the vapor pressure of pure oxides and sulfides, much more work will be required before we can obtain an adequate understanding of the rôle played by these compounds in various geologic processes.

The occurrence of volatile compounds undoubtedly is an important factor in the processes by which various elements can be concentrated in nearly pure form and thus made available for practical use. From the analysis of many thousands of rocks it is known that 8 elements constitute 99% of the Earth's crust. These elements, in order of their abundance, are oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. The other 84 elements occur in notably small amounts and if, as believed by many, the Earth was quite homogeneous at the time of its formation, the concentration of the rarer elements must have taken place by subsequent physical-chemical processes. Just as various types of rocks are believed to have been formed by differentiation from a homogeneous parent magma, so on a smaller scale but in a more complex manner the various minerals containing one or more elements have been concentrated through processes of solution and solidification, or volatilization and deposition.

Acid gases play an important part in the activity observed in the vicinity of volcanoes and fumaroles. Although the principal constituent of volcanic gases is always water vapor, notable amounts of hydrochloric and hydrofluoric acids, hydrogen sulfide, carbon dioxide, and other compounds, such as boric acid, are found in some incrustations. The barium content was found to be one hundred times that observed in the adjacent pumice. This furnishes a striking example of the concentration of the minor elements by processes taking place before our eyes.

Well-defined crystals of magnetite (Fe_3O_4) occurring in some incrustations were subjected to chemical analysis and found to contain elements other

than the iron and oxygen. Among these elements were lead, copper, molybdenum, tin, antimony, titanium, zinc, nickel, cobalt, and manganese. By further study of various incrustations the presence of still other elements was demonstrated. Nearly all these elements have one characteristic in common—that their halides, and in some cases also their sulfides and oxides, are appreciably volatile at the temperatures prevailing in fumarolic gases at the time they are emitted. There is little doubt that the volatility of various metallic compounds is an important factor in the segregation of elements originally present as mere traces in the igneous material and in the formation of mineral deposits of economic importance.

EQUILIBRIA IN SYSTEMS CONTAINING WATER AND OTHER VOLATILE COMPONENTS

Boron oxide—water. The equilibrium diagram of this system has been established and the results prepared for publication [Kracek, Morey, and Merwin]. Boron trioxide is a constituent of many minerals occurring in nature under conditions that indicate widely differing modes of origin. In industry borates are used as constituents of enamels and special-purpose glasses. The presence of B_2O_3 in these products imparts toughness and other beneficial properties, such as low coefficient of expansion, and resistance to devitrification. Unusual experimental difficulties are encountered in the investigation of some parts of this system. At high B_2O_3 concentrations the solutions are very viscous and equilibrium is attained only after long periods of time; at other concentrations the occurrence of metastable compounds complicates the interpretation of the measurements.

The crystalline phases which occur in this system are ice, H_3BO_3 , three modifications of HBO_2 (monotropically related to one another), and B_2O_3 . The freezing-point—solubility curve for H_3BO_3 rises smoothly from the ice- H_3BO_3 eutectic to a maximum at the metastable melting-point of H_3BO_3 , $170.9^\circ C.$, and then descends to the metastable eutectic for H_3BO_3 and one of the metastable forms of HBO_2 .

Crystalline B_2O_3 was formed from solution in silica tubes, and also in open vessels at atmospheric pressure, by establishing the conditions necessary for spontaneous crystallization. The oxide never crystallizes spontaneously from the nearly anhydrous melts of vitreous B_2O_3 . Curiously enough, crystallization appears to be initiated by the presence of the stable form of HBO_2 but not by the other modifications of this compound. Boron trioxide melts at 450° . Its solubility curve has been determined from the melting-point down to the intersection of the curve for the stable modification of HBO_2 (at $235^\circ C$) and also to the metastable eutectic involving the second modification of HBO_2 . From the slope of the solubility curve the latent heat of fusion of B_2O_3 has been estimated to be 97 calories per gram.

Boron trioxide is an unusually interesting substance. In its vitreous form it is tough rather than brittle, and this property appears to be shared to a considerable extent by the crystalline form which, although lying below steel on the hardness scale, resists crushing to an extraordinary degree. Like the other boron compounds in this binary system, the crystalline form is denser than the liquid or glassy form. Further investigations on the optical

properties are in progress, but it has already been established that the crystals are nearly or quite uniaxial, with the highest index of refraction equal to about 1.65.

Calcium sulfate—water. During the past year the work on the system, $\text{CaSO}_4\text{—H}_2\text{O}$, has been completed [Posnjak]. Of the solids appearing in this system, gypsum, anhydrite, and hemihydrate are of considerable technological importance, and the first two are minerals which present also much geological interest on account of the occurrence of gypsum and anhydrite in many sedimentary deposits. The conditions governing their formation have been the subject of numerous investigations; the most extensive of which was carried out almost forty years ago by J. H. van't Hoff and his associates as part of their classical work on the formation of the Stassfurt salt deposits. But later investigations of the system, $\text{CaSO}_4\text{—H}_2\text{O}$, did not always confirm the earlier work. The present research on the controversial problems has shown that the results that were based entirely on indirect determinations of vapor pressures are erroneous. No dissociation reaction of gypsum to anhydrite, or gypsum to "soluble anhydrite," takes place. On the contrary, when gypsum dissociates under ordinary conditions, hemihydrate (plaster of Paris) is invariably formed.

In the system, $\text{CaSO}_4\text{—H}_2\text{O}$, reliable information on the relationship of the various phases has now been obtained directly from solubility data. The geologically important transition point, gypsum-anhydrite-solution-vapor, lies at 42°C . It has been shown that, contrary to van't Hoff's conclusion, deposition of anhydrite at ordinary temperatures does not require a high concentration of salt solutions, but may take place even in fairly dilute solutions, depending on the extent to which the relative solubilities of gypsum and of anhydrite are affected by added salt. This finding bears directly on the definition of the conditions necessary for the formation of deposits of gypsum and of anhydrite of marine origin. Experiments are now in progress to determine the effect of sea water on the stability relations.

Sodium disilicate—water. Our apparatus for quenching silicate mixtures in steam under high pressure has given satisfactory results. Experiments have been made at pressures up to 2500 pounds per square inch. The electric furnace is enclosed in a gas-tight bomb of stainless steel 6 inches in external diameter, closed at top and bottom by stainless steel covers, and the joint made tight with a gold washer. A system of baffles entirely eliminates trouble from convection currents.

Among the simple systems containing volatile components are the binary and ternary systems composed of water together with silicates of the alkali metals. We are especially interested in the upper part of the solubility curves in such systems and are investigating the lowering of the freezing-point of some silicates by the addition of water. The system, $\text{H}_2\text{O—Na}_2\text{O—SiO}_2$, is being investigated and the results for the pressure—temperature curve of the binary system, water—sodium disilicate, have already been completed [Morey and Ingerson]. Sodium disilicate, which in the absence of water melts at about 875° , under increasing steam pressure melts at successively lower pressures, the lowering of melting point at 2000 pounds per square inch being 145° . As the temperature falls, the rate of pressure increase becomes greater,

but a pressure maximum, which is to be expected from various considerations, has not yet been reached. Special experiments with sodium metasilicate showed that the volatilization of sodium oxide with steam was too small to be detected.

Sodium hydroxide—water. A systematic investigation of the important 5-component system, $\text{Na}_2\text{O}—\text{K}_2\text{O}—\text{Al}_2\text{O}_3—\text{SiO}_2—\text{H}_2\text{O}$, obviously requires a thorough knowledge of the various binary systems. Strangely enough, adequate information on the simple system, $\text{NaOH}—\text{H}_2\text{O}$, has not hitherto been available. An apparatus has now been devised for stirring and filtering mixtures of these two components while they are maintained at a moderate temperature and pressure. The liquidus temperatures near the melting-point of sodium hydroxide monohydrate at 65° have been measured, and a part of the system, $\text{NaOH}—\text{Na}_2\text{CO}_3—\text{H}_2\text{O}$, has been investigated [Morey and Burlew].

Systems containing two volatile components. Such systems are of interest for several reasons. The general problem involving the presence of two volatile components is one that must be considered in nearly all geologically important cases of transport of material through a vapor phase. Special interest attaches to the combined behavior of the components H_2O and CO_2 because in the study of systems containing soda or potash the presence of carbonates is inevitable whenever the alkali content becomes greater than that corresponding to metasilicates. The vapor phase will contain both water and carbon dioxide, and the relative proportions of the two under varying conditions must be determined. The inclusion of carbon dioxide as a component, therefore, not only constitutes an important step in our program, but is inevitable on account of the chemical behavior of the materials in the laboratory. Some important studies in this field [Morey and Fleischer] are nearing completion.

Behavior of solutions under high pressure. The study of the effect of moderate pressures on liquid solutions has been continued, the object being to correlate the effect of pressure on solubility, the volume changes on mixing, and the compressibilities of aqueous solutions with known properties of the pure components. Three main lines have been investigated during the year.

(1) At various pressures up to 1000 bars, and at ten-degree intervals between 25 and 65° , we determined the compression of the non-polar liquid, benzene. From the data important thermodynamic constants of benzene were computed [Gibson and Kincaid]. The results threw considerable light on the constant B in the Tait Equation, $k = C \log(1 + P/B)$, which we have used for extrapolation of results along the pressure axis. By analogy with van der Waals' equation, B appears to represent the difference between the pressure set up by the intermolecular attractive forces in the liquid and the thermal pressure. In the same work a new method was developed for determination of the effect of pressure on the refractive index and dispersion of benzene, and good results were obtained. Conclusions as to the most suitable empirical equations for representing the effect of pressure on the refractive index are in accord with recent work by other investigators.

(2) Hitherto our work on the compressions of solutions has all been at

25°, but this year a start was made on a study of the effect of temperature on the compressions of water and aqueous solutions [Gibson and Loeffler]. In order to supply data on the volumes of solutions at 1 atmosphere at temperatures between 25 and 100° a weight dilatometer of quartz was developed and has given excellent results. The specific volumes of water and of solutions of sodium chloride and sodium bromide over the entire concentration range have now been measured at 1, 500, and 1000 bars at temperature intervals of 10° between 25 and 85°. It is of interest to note that the apparent volume—temperature curves for these salts pass through maxima below 95°.

(3) A study of our previous results and of the results of the current work has been made for the purpose of finding what generalizations may be made concerning the effect of pressure on the solubility of solids in liquids. In this analysis several interesting relations were discovered, and it was concluded that sparingly soluble polyvalent salts must have their solubilities in water raised by pressure and that the pressure coefficient of the solubility of these substances, while it decreases slightly from 25 to 70° (approximately), increases as the temperature is raised above 70°.

NON-AQUEOUS SYSTEMS

Albite—nephelite (carnegieite). An investigation of the phase relations in the binary system, albite—nephelite, has been completed [Greig and Barth]. At 1254° nephelite inverts reversibly to the modification, carnegieite, which melts at 1526°. Systems containing compounds with an inversion afford an important test of solid solution. Upon addition of the second component to the substance, if more of the second component dissolves in the low-temperature form than in the high-temperature form, the inversion temperature is raised. On the other hand, if more dissolves in the high-temperature form, the inversion temperature is lowered. Very few examples have been completely worked out, but this system provides an interesting illustration of the above principle. By the addition of albite to nephelite, the temperature of the transition is steadily raised and reaches 1282° at the limit of solid solution, which at this temperature corresponds to 16 weight per cent albite in the albite-nephelite mixture. Considerations based on crystal structure indicate that it is not probable that a second component will enter into solid solution to a like extent with two crystalline modifications of the substance. The occurrence of solid solution, therefore, can usually be detected by a change in the inversion-temperature. In the present instance more solid solution takes place with nephelite than with carnegieite.

Pure albite melts at 1118°, according to the most recent determination, and is remarkable for the slowness with which the crystalline material changes to liquid at temperatures even a considerable distance above the melting-point. Our experience with silicates indicates that the persistence of the crystalline state at temperatures above the melting-point is a general property of silicates and possibly of all matter in the solid state, the behavior of various materials constituting a difference in degree rather than in kind.

An actual determination of the melting-point of a substance like albite requires special care. It is important to recall that the melting-temperature

of a crystalline substance (that melts congruently) is the temperature at which it can coexist in equilibrium with a liquid of the same composition, and that above this temperature the equilibrium state is one of complete liquidity, and below it of complete crystallinity. For substances whose fusion reaction proceeds so rapidly that they can not be heated appreciably above their melting-temperature without melting, a failure to observe fusion at a given temperature is sufficient indication that this temperature is below the melting-point. On the other hand with a material like albite, although the fact that it has melted at a given temperature shows that the melting-temperature has been exceeded, failure to obtain melting does not show that the melting-point has not been exceeded. A definite criterion is the growth of crystals. If this takes place, we know that the temperature at which the growth occurs is below the melting-point. The procedure then is to find a temperature at which crystals of albite, for example, change to albite liquid, and a second temperature at which they definitely increase in size, surrounded by a liquid of the same composition. Small crystals of albite were grown in a homogeneous glass of albite composition. Material so prepared was held at a chosen temperature and then by means of the petrographic microscope compared with the original material. An unmistakable change in the size of the albite crystals indicated whether the chosen temperature was above or below the melting-point, which could thus be shut in between two limiting temperatures. Obviously the spread between these two limits can be narrowed to any desired extent by holding the material at a series of constant temperatures for a sufficiently long time.

On the basis of composition the mineral jadeite, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$, belongs in this binary system, but jadeite was found not to be stable in contact with the liquid, and does not appear in the equilibrium diagram within the temperature range that has been investigated. Jadeite does not occur in the common igneous rocks and has been considered by petrologists to be stable only at high pressures.

Leucite—diopside—silica. Special interest attaches to the melting phenomena of olivines and pyroxenes, which are among the early minerals to crystallize from a cooling magma, and of the alkali-alumina silicates which are among the late minerals. We have been studying the behavior of systems which combine one of the early-forming minerals with late-formed minerals, in order to ascertain the nature of the residual liquids from fractional crystallization of such systems. Measurements have now been completed for the system, leucite—diopside—silica, which combines one of the simplest pyroxenes, diopside, with the alkali-alumina silicates, leucite and potash feldspar [Schairer and Bowen]. In this system there are no ternary compounds. The field of diopside occupies a large part of the ternary diagram, and with mixtures containing even less than 2% diopside in total composition, diopside appears as the primary phase. Ordinarily, therefore, upon crystallization diopside is removed almost quantitatively, leaving residual liquids that in composition approach a mixture of potash feldspar and silica.

Rock-forming pyroxenes. These are among the most complicated minerals of the igneous rocks. They are polycomponent solid solutions involving the compounds, CaSiO_3 , MgSiO_3 , FeSiO_3 , MnSiO_3 , in addition to Al_2O_3 , Fe_2O_3 ,

and often TiO_2 . During the past year exploratory studies were made to ascertain if it was possible to obtain equilibrium data on silicate mixtures containing, among other things, FeO and Al_2O_3 . A study of mixtures on the join, anorthite—fayalite, showed that these mixtures are quaternary in their behavior but amenable to study by the method of quenching in iron crucibles in an atmosphere of nitrogen. The preliminary results suggested that the first step in determining the rôle of Al_2O_3 in the augite was the complete study of the fundamental system, $\text{FeO—Al}_2\text{O}_3\text{—SiO}_2$. This has been undertaken and very substantial progress has been made on it. In this system no ternary compounds appear on the liquidus surface. During the coming year the investigation will be pressed to completion, and experiments will be started on portions of the quaternary system, $\text{CaO—FeO—Al}_2\text{O}_3\text{—SiO}_2$, the next step in the attack. It is worthy of note that the system, $\text{FeO—Al}_2\text{O}_3\text{—SiO}_2$, is of interest not only to the petrologist but also to the metallurgist. Many blast furnace slags from high-alumina ores approach compositions in this system.

Alkali-alumina silicates. Among the silicate systems just completed is the system, $\text{K}_2\text{O—Al}_2\text{O}_3\text{—SiO}_2$, which was begun in 1932 and has required six years of continuous effort to complete. The diagram for this system depicts the complete melting relations of the two important rock-forming minerals, leucite (KAlSi_2O_6) and potash feldspar (KAlSi_3O_8). Measurements on nearly 450 different compositions were required for the complete melting diagram, which shows the behavior of these minerals with either an excess of alkali or of alumina. This system and the system, $\text{Na}_2\text{O—Al}_2\text{O}_3\text{—SiO}_2$, (which is now well along toward completion) are directly applicable to many fields of chemical technology, such as the glass and the ceramics industries.

Other systems. Among other systems the investigation of which has been completed are the binary systems, wollastonite—diopside and wollastonite—akermanite, and the ternary system, nephelite—fayalite—silica. The systems, soda—alumina—silica, leucite—anorthite—silica [Schaier and Bowen], potassium disilicate—sodium disilicate [Kracek], and gold—silver—tellurium [Tunell, Ksanda, and Kracek], are either practically finished or rapidly approaching completion.

SPECIAL PHYSICAL METHODS FOR THE STUDY OF STRUCTURE AND PROPERTIES

X-ray methods. Improvements in experimental technique have facilitated the use of X-ray methods in our research problems and have permitted the application of these methods to a great variety of substances. Although the study of organic substances seems far removed from silicate research, it is of interest and importance to study the orderly arrangement of simple crystals formed at moderate temperatures merely by the laying of one molecule against another, in contrast with the complex rock-forming minerals formed at much greater temperatures. Careful study of a few fundamental types should lead to generalizations governing that enormous and continually increasing number of organic substances with which the progress of modern organic chemistry has made us familiar, and quantitative data concerning

the molecular symmetry of simple compounds should give aid in the interpretation of structures of a more complex nature.

Recent determinations [Ksanda and Tunell] of the unit cell and space-group of glycine (one of the simplest of the organic compounds) have not only aided in the physical-chemical study of the system, glycine—water, under high pressure but have also yielded results of interest from the standpoint of crystal structure. Crystals of organic substances are frequently of low symmetry or are completely asymmetric. Consequently the majority of organic substances crystallize in the monoclinic system. Since the scattering powers of carbon, nitrogen, and oxygen are very nearly the same, they can not be distinguished with certainty by X-rays; moreover, the determination of the change of atomic positions with the state of chemical combination is difficult. The atomic arrangement in most organic crystals—consisting of many parameters—forms a structure that is bound molecule to molecule by forces of weaker nature than those existing between the atoms in gaseous molecules.

A study of samples of tungsten wire 0.115 mm diameter, from which the springs for our gravity meter are made (see below), was carried out by means of X-rays. The pinhole method, with a circular camera and monochromatic Cu-K radiation filtered through nickel foil, was used. A series of photographs, under the same conditions of exposure and development, was taken of (a) drawn tungsten wire, previous to forming into the desired shape, slightly annealed but not heat-treated, (b) part of a finished spring, heat-treated at 1200° C. for two hours in a specially built furnace, in which the air was displaced by hydrogen, and (c) part of a finished spring, heat-treated for two hours at a temperature of 1300° C.

The diffraction lines in (a) are uniformly broad, and the lines of higher planes show no resolution of $K\alpha_1$ and $K\alpha_2$ doublet—thus indicating residual deformation of the lattice arrangement. This deformation causes variable atomic spacings and a departure of the oriented particles from perfect alignment.

In (b) the diffraction lines are sharp and of uniform density, and the reflections from planes hkl 123 and 400 begin to resolve into the α_1 and α_2 doublet, which indicates that recrystallization to a fine crystalline structure consisting of grains oriented perfectly at random has taken place. The physical properties of such a structure should be nearly the same in all directions. In tests and practical use, a spring receiving such heat-treatment was found entirely satisfactory. Heat-treatment at higher temperatures produced a structure having larger size crystals, evidence of which is noticeable in (c); the diffraction lines in this spectrogram are beginning to show a pronounced Laue effect. A spring heat-treated at a temperature above 1200° C. was found to be unduly brittle.

Measurement of diffraction lines of these films and the unit cell dimension calculated from them (with correction applied for unresolved diffraction lines) gives the value for $a_0 = 3.158 \pm 0.005$ Å. Metallic tungsten has a body-centered type lattice, and belongs to space-group O_h^2 — $m\bar{3}m$. There are two molecules of W in the unit cell.

The annealing temperature and the heat-treatment of tungsten wire used for springs are very important and determine the mechanical properties of the finished spring. Heat-treatment under controlled conditions produces a marked effect on the lattice arrangement and the size of the grain.

Raman spectra. The work of the past year has been a continuation of the attack on the general problem of molecular constitution by spectroscopic methods [Hibben]. To this end several types of compounds were investigated. The first group consisted of methyl methacrylate and its polymers, and diethyl fumarate and maleate. These substances give Raman spectra containing a number of lines characteristic of the molecular constitution. The presence of the ethylenic ($C = C$) grouping is shown by the Raman

shift near $\Delta\tilde{\nu}$ 1650 cm^{-1} , and the $\begin{array}{c} H \backslash \\ C = \\ H / \end{array}$ structure by some vibrations above

$\Delta\tilde{\nu}$ 3000. On comparing the relative intensities of the carbonyl ($C = O$) displacements with the ethylenic ones, we conclude that the unpolymerized methyl methacrylate is more closely related to the *cis* isomers than to the *trans* isomers. In the polymers of methyl methacrylate, which form organic glasses, the ethylenic and the hydrogen displacements are completely absent. This shows that polymerization takes place through the unsaturated carbon atoms, with the production of large molecular aggregates which tend to form glasses. It is highly probable that the inorganic silica glasses are built up in the same manner. These experiments also show the enormous effect of a small amount of polymerization on the viscosity of liquids.

Another group of compounds investigated included zinc chloride, which possesses a valence that may be homopolar or heteropolar. In dilute solutions it ionizes to zinc and chlorine ions. The spectrum of a concentrated solution of this compound indicates that the ionization in such solutions is repressed and that a large portion of the molecules exist in the un-ionized state. The addition of a common chloride atom was found to repress still further the ionization, while other zinc salts had little effect.

A pair of closely related isomers, α -methyl glucoside and α -methyl mannoside, was examined. The spectra obtained for these two substances are entirely different, although there is a common general pattern. The 180° rotation of one of the $H-C-OH$ groups around the central axis disturbs the symmetry of the molecule and alters the whole spectrum. This result is important because it shows that the specific heat—which depends on these vibrations—and other physical properties may be changed profoundly by a slight change in symmetry.

From the results of a study of boric acid and its salts it was concluded that boric acid is a molecule of the type AB_3 having the symmetry D_{3h} in which all the B groups lie at the corner of a plane triangle with the boron atom in the center, and that the BO_2 ion is non-linear and has a bent structure with the symmetry C_{2v} . Sodium tetraborate was found to dissociate, on solution, into sodium metaborate and boric acid. Sodium hydroxide when added to boric acid solutions causes the immediate formation of sodium metaborate, and hydrochloric acid added to an aqueous solution of sodium tetraborate produces boric acid. All these changes may be demonstrated

by means of the Raman effect without affecting the condition of the solutions. The spectrum of crystalline sodium tetraborate is consistent with the view that both crystals and glass are made up of long chains of BO_3 and BO_2 groups.

The most recent investigation in this field is the critical and detailed study of crystals of the type represented by calcite, aragonite, and barite. A number of new Raman lines found in these crystals are combinations and harmonics of other lines some of which are "forbidden" as fundamentals in the Raman effect. When the complete spectra are obtained it may be possible to coordinate the spectra with the specific heats of the compounds, for there are several lattice vibrations which undoubtedly contribute to the specific heat. The effect of temperature on the Raman spectra of crystals is being studied.

Optical methods. Probably the most nearly indispensable tool in silicate research is the petrographic microscope. With this instrument precise measurements for purposes of identification are made on minute fragments of materials by the use of an elaborate technique that was devised many years ago and subsequently has been continuously developed and improved. An important class of measurements depends upon observations of interference figures in crystals through which polarized light is passed. Crystals of many compounds are so strongly birefringent and dispersive that interference figures obtained by illumination with white light are indefinite. In monochromatic light a clear set of black curves may be seen but not the order of interference or the direction of its change. A significant improvement in the examination of such materials has been made [Merwin and Greig] by selecting filters that transmit a band of sharply contrasted colors, e.g. orange to yellow-green, or by choosing a filter or combination of filters that transmit two very narrow bands, e.g. red and green.

Optical determination of the constituents of clays and other deposits, such as those of the floor of the ocean, offers special difficulty and requires the application of special methods. Careful examination of the ocean-bottom samples collected by the *Carnegie* revealed the presence of dolomite in widely separated areas in the Pacific Ocean far removed from land [Merwin and Posnjak]. It becomes evident that the composition of the sea water is such that dolomite can and does deposit directly from solution. The fact that dolomite can be produced directly rather than by replacement throws light upon an important class of sedimentary deposits.

Increasing use of the methods of petrofabric analysis is being made in the investigation of rocks. Important advances in technique whereby the three-dimensional arrangement of mineral grains and various details of structure are accurately fixed with reference to the original orientation of the specimen [Ingerson] allow us to infer the kind of movement that has taken place in masses of deformed rock.

Electrical properties of multilayers. Crystalline substances found in nature are electrically neutral. This is due to the circumstance that although in the crystal lattice there may be molecules present which possess permanent electrostatic moments, such molecules are grouped in pairs or

sets so arranged that an internal compensation of their electrical fields takes place.

Recently, in connection with their discovery of a method of producing multilayers of long chain molecules, Langmuir and Blodgett of the General Electric Company succeeded in depositing on metal surfaces as many as 3000 layers of molecules. They found it possible to prepare two types of multilayers of calcium stearate, called the Y type and the X type. In the Y type multilayer, although all the molecules in one layer are oriented alike, the molecules in the adjacent layer are oriented in the opposite direction, whence the electrical fields due to the first, third, and fifth layers, for example, are compensated by the electrical fields of the molecules in the intermediate layers, that is, the second, fourth, and sixth. The structure of a Y multilayer of calcium stearate was found to be precisely the same as that of ordinary calcium stearate. From their experimental results they also concluded that the molecules in the X type multilayer of calcium stearate were all oriented in the same direction.

Subsequently, Porter and Wyman of the Harvard Biological Laboratory reported that the X type of multilayer, when deposited on chromium, was characterized by an electrical field which in their experiments produced a potential difference of $8\frac{1}{2}$ volts, with about 160 layers. From these results we inferred that the electrical phenomena found by Porter and Wyman were a demonstration of the existence of a lack of compensation in the electrical fields of the molecules in the X type multilayer. In conformity with the structural ideas advanced by Langmuir and Blodgett, we concluded also that since this would mean a volume polarization of the X type multilayer, such a material, if deposited on a non-conductor and suspended in an electrical field, would develop a rotation which would be proportional to the electrical field, to the area coated with the layer, to the number of layers in the multilayer, and to the electrical moment of the individual molecule.

Although there have been many attempts to produce a permanent volume polarization in crystals for the purpose of obtaining the electrostatic analogue of a permanent magnet (the electret, about which Oliver Heaviside speculated years ago), no one had succeeded in producing an electret with a polarization strong enough to be of practical value. Our calculations, based on the results of Langmuir and Blodgett, as well as those of Porter and Wyman, showed that the rotations one would expect to observe were large enough to be measured, and possibly might be large enough to prove of use in the construction of indicating instruments.

In the earlier work X type layers were deposited only upon polished glass and certain polished metals. We were able to produce the deposits upon mica, ebonite, cellulose triacetate, and methyl methacrylate. We also succeeded in preparing films containing as many as 350 X type layers [Goranson and Zisman], and we have been able to demonstrate that the rotations observed in an electrical field are of the order of magnitude predicted by our calculations. In addition, we have observed an interesting phenomenon, which may be called the "electrolysis effect" and apparently is due to the presence of ions throughout the volume of the multilayer. Although the calculated order of magnitude of the electric moment seems to be correct

for a moment caused by dipoles, the presence of ions, shown by the electrolysis effect, and the existence of other phenomena that still await explanation, have indicated the need for further measurements of the magnitude of the charges within the multilayer. The adsorption of calcium ions on the surfaces probably accounts for various phenomena reported by other investigators.

Thermal properties of rock-forming minerals. Little information has been available concerning the specific heats and the heats of fusion of the silicates. In view of the growing emphasis on the thermodynamic aspects of geologic problems, it has become increasingly important to develop the facilities for routine determination of thermal properties as they become needed.

Unlike the metals, most silicates fail to crystallize when melted and suddenly cooled. Consequently the "dropping method," which depends on measuring the heat liberated when the melt crystallizes, is not generally applicable. Thermochemical means have been employed in selected cases, but such methods are difficult and may be subject to concealed errors that must be evaluated or proved negligible before the results can be accepted with confidence. At low temperatures, heats of melting are quite commonly determined by a direct measurement of the energy that must be supplied to a sample in order to transform it from solid to liquid. It seemed probable that, at the much higher melting-temperatures of the silicates, this direct method would be subject to serious errors due to thermal and electrical leakage and that measurement and adequate control of temperature would be difficult. On the other hand it seemed likely that by careful design of the apparatus these errors might be reduced to a point where adequate data could be obtained in a large proportion of cases.

Accordingly a preliminary study of the method was begun, using, for the most part, existing laboratory equipment. As stated in the Annual Report for last year, enough information was thereby obtained to warrant building the specialized apparatus needed for routine determinations at temperatures below 1300°. This apparatus is now in operation, and the heats of melting of K_2SO_4 and Na_2SiO_3 have been determined [Roberts] at their respective melting-points (1069° and 1089°). Data obtained in making several determinations of each of these quantities indicate that we may expect an uncertainty probably not greater than 5 per cent in determinations made below 1200° or possibly 1300°. At still higher temperatures the relative importance of the various corrections is so great that a modified apparatus will probably be desirable.

FIELD WORK

Ocean-bottom sampling. For the purpose of securing additional cores from the ocean-bottom, and especially from the great depths where the bottom lies more than 5 miles below the surface of the water, a portable sounding apparatus has been obtained and is now being put in working order for early use on board ship [Piggot]. The apparatus consists of a winch with 5200 fathoms of steel cable, operated by a Diesel engine having sufficient power to reel in the cable at an average speed of 300 feet per minute. Features that will expedite the difficult task of lowering to the bottom the

heavy combination of sampling device and cable and bringing the sample back to the surface are (1) a hydraulic brake used separately or in conjunction with a mechanical brake, (2) a spooling device with continuously variable ratio, and (3) a special shock absorber, or torque arm, for reducing the strain on the cable caused by the pitching or rolling of the ship.

Because a steel cable of uniform section 5000 fathoms long, hanging freely from one end, is not sufficiently strong to support its own weight (with any reasonable factor of safety), recourse was had to a suitable "tapered" cable. This consists of six sections varying in size from $\frac{5}{16}$ inch to $\frac{5}{8}$ inch in diameter, the smallest section being at the bottom end and the various sections being carefully spliced together. From tests of tensile strength it was found that we have a factor of safety of three. The winch is supported on a base approximately 6 feet by 9 feet, and the combined weight of winch and cable is about 12 tons.

Volcanological studies at Montserrat. An important phase of the volcanological program has been the investigation of the volcano on the island of Montserrat by Research Associate F. A. Perret in cooperation with the Geophysical Laboratory. Additional observations of the volcanic and seismic activity on this island have been supplemented by studies on a new and similar phase of activity at Dominica. The volcanoes of the Lesser Antilles, with their accessible peaks, continuing activity, and alternating periods of volcanic and seismic phenomena, have afforded a valuable opportunity for research in this field. A new type of microphone, constructed as a complete and self-contained unit and well adapted to volcanological research, has been developed. Continuous records of sulfide gases were obtained at Montserrat and the new shock-recorder, or "seismeter," was installed at Dominica. The success attained through the use of these instruments at various centers has served to emphasize the great advantages of quantitative measurement in the study of volcanoes. The complete report of the observations at Montserrat which has now been prepared for publication marks a definite advance in our knowledge of the behavior of volcanoes.

Gravity measurements. The new gravity torsion meter referred to in the Annual Report of last year has been built in the Laboratory and is now ready for thorough test in the field [Wright and England]. In the new design the effort has been made to produce a lighter and more compact instrument with effective insulation and with all parts easily accessible. The principle of the instrument has, however, remained unchanged; the torsion element is kept at constant temperature and under constant reduced air pressure of one millimeter of mercury; it is, moreover, placed under strain only during the four to six minute period required to occupy a station. At other times it is held at rest in order that the strains introduced during a measurement may be dissipated. As a result of this careful treatment of the torsion element the readings of the old instrument remained constant for any given station to one part in a million over an eight-month period of field test during which many stations were occupied.

In the new instrument the housing is made of an aluminum alloy of high mechanical strength, the optical system and the graduated circle and

vernier arc are mounted inside the housing, and the rotating support for the torsion spring is a single casting. The levels are attached to the housing and can be viewed through a single lens tube without disturbing the instrument. The housing is encased in well-insulated stainless steel drums. Constancy of temperature is maintained by use either of ice or of an electrically heated thermostat. For field use the instrument is carried in a light motor truck with insulated walls. To occupy a gravity station the apparatus is shifted to a heavy tripod that reaches through the floor of the truck to the ground. Measurements can then be made inside the truck regardless of weather conditions.

Projected volcanological investigation in Central America. This is a region containing an unusual number of active volcanoes. Preliminary studies in 1932 and 1935 showed many features of interest and pointed to the desirability of a thorough and systematic investigation of volcanic activity in a selected area in the region. Detailed plans have been worked out for field studies in cooperation with other agencies and it is hoped that funds will become available for this program. It is possible to learn something of the underground structure in the vicinity of an active volcano by the application of modern physical methods. Measurements of gravity with our portable gravity meter, magnetic surveys, measurements of Earth resistivity, chemical studies of volcanic products, and an investigation of the pertinent geologic relations are the principal methods by which we expect to gain further information on the origin of volcanoes and the nature of volcanic processes.

SUMMARY OF PUBLISHED WORK

(947) A bomb for use in hydrothermal experimentation. George W. Morey and Earl Ingerson. *Amer. Mineral.*, vol. 22, pp. 1121-1122 (1937).

An illustrated description of an improved bomb for use in hydrothermal experimentation.

(948) The availability of optical glass in America. George W. Morey. *Jour. Optical Soc. Amer.*, vol. 28, pp. 5-7 (1938).

Optical glass is the material available to the designer for the calculation and construction of lens systems in which the many possible defects and aberrations are reduced to a minimum. It is characterized by the perfection of certain physical properties, obtained by extreme care in manufacture, and by a wide range of optical properties, obtained by change in composition.

The physical properties which characterize optical glass are almost perfect homogeneity and high transparency. Freedom from bubbles is also important, but in this respect optical glass does not differ from other types of glass such as ophthalmic glass or even plate glass, and for many uses a few small bubbles do no harm and are less objectionable than in plate glass.

The optical glass industry in this country at the close of the War had developed a tremendous potential capacity. The types of glass manufactured were limited to those few which are the irreducible minimum for military needs, far fewer than are needed for general optical purposes. Four firms were engaged in the manufacture of optical glass, but of these only one has continued production. That company manufactures a wide range of glass types and could produce any additional types for which demand might develop.

(949) Olivine fourchites from Raymond Fosdick Mountains, Antarctica. Clarence N. Fenner. *Bull. Geol. Soc. Amer.*, vol. 49, pp. 367-400 (1938).

A collection of ultrabasic rocks from an extinct volcano had been made by the Second Byrd Antarctic Expedition and the rocks were brought to the Geophysical Laboratory for study. Their physical and mineralogical make-up was such as to render possible a separation of their component minerals. Analyses of the products were made. With this information, a comparison of the actual course of crystallization of the magma with what has been deduced from the theory of crystal fractionation was possible.

The aphanitic groundmass, freed of phenocrysts, was found to have an ultrabasic composition. Therefore it is concluded that wholly liquid ultrabasic magmas exist.

Comparison of compositions of phenocrystic pyroxene and groundmass pyroxene shows changes during the course of crystallization that are hardly in accord with those that have been deduced as generalizations from experimental work and that have been used in support of the theory of crystal fractionation.

The view is expressed that experimentally investigated systems represent, on the whole, simpler conditions than exist in natural magmas; and that inferences derived from the behavior of these comparatively simple laboratory melts have been broadened and generalized to cover conditions to which they are hardly applicable.

(950) The nature of solutions and their behavior under high pressures. R. E. Gibson. *Scientific Monthly*, vol. 46, pp. 103-119 (1938).

In this lecture, delivered at the Administration Building of the Carnegie Institution of Washington, the broader problems raised by a consideration of matter in the depths of the Earth are described, together with the methods by which these questions are broken down into simpler specific problems to which known experimental and theoretical technique may be applied. The problem of the effect of pressure on solubility is reduced to one of determining either experimentally or theoretically the volume changes on mixing and the compressibilities of solutions and their components. The results of a study of the compressibilities and volume changes on mixing of a large number and variety of solutions (see *Laboratory Papers* 839, 843, 870, 883, 918, 926, 941) are reviewed and an attempt is made to interpret them in the light of current ideas on the nature of solutions. In particular, the specific effects of different electrolytes when dissolved in water are discussed and it is pointed out that these effects may be well explained if the effect of the volumes of the dissolved ions on the internal pressure of the water is taken into account.

(951) The influence of temperature and pressure on the volume and refractive index of benzene. R. E. Gibson and John F. Kincaid. *Jour. Amer. Chem. Soc.*, vol. 60, pp. 511-518 (1938).

The work described in this paper was undertaken by the authors with two objectives in mind, namely, to examine the Tait equation used for expressing the volume of a liquid as a function of pressure over a temperature and pressure range for a simple non-polar liquid, and to try out a new method for estimating the change with pressure of the refractive index of liquids.

The compressions of benzene to different pressures between 1 and 1250 bars were measured at 10° intervals between 25 and 65°. The compressions were well represented by the Tait equation $k = C \log \left(\frac{B + P}{B} \right)$ and it was found that the constant C was independent of temperature. From these results important thermodynamic properties of benzene were computed over a range of pressure and temperature. A study of the temperature variation of the constant B showed

that it could be introduced empirically into an equation of state of the van der Waals' type and that B represented the difference between the thermal expansive pressure and the cohesive pressure due to the attractive forces between the molecules.

The method employed for measuring the effect of pressure on the refractive index of benzene consisted of adjusting the pressure (at constant temperature) until the refractive index of the benzene exactly matched that of a fragment of optical glass immersed in it. The match was determined by visual observation through a microscope, monochromatic light being used. The refractive index of the glass changed very little with pressure and its change could be computed from the compressibility of the glass. Measurements were made over a range of 20° and 1200 bars pressure. The results were fitted exactly by the Eykman equation which represents the refractive index as a function of the volume; indeed, it was shown that with the help of the Eykman equation the compressions of benzene could be computed from the refractive indices at different pressures about as accurately as they could be measured directly.

(952) Core samples of the ocean bottom and their significance. Charles Snowden Piggot. *Scientific Monthly*, vol. 46, pp. 201-217 (1938).

An address delivered at the Administration Building, Carnegie Institution of Washington, November 23, 1937.

The least disturbed geologic record of the relations which have existed between the continental elevations and the oceanic basins is the sediment at the bottom of the sea. Early efforts to study the sea-bottom are briefly referred to and an apparatus which has secured more adequate samples from great depths is described in some detail. Certain geophysical problems which may be attacked by an appeal to this ocean-bottom record are discussed—more particularly the accumulation of radium in the deep sediments—and the significance of such studies in the future is considered.

(953) The application of the Raman effect to petroleum chemistry. James H. Hibben. Reprinted from "The science of petroleum," Oxford University Press, 1938, pp. 1206-1212.

This is an outline of the elementary theory of the Raman effect and its application to the field of petroleum chemistry. It is pointed out that all hydrocarbons and their derivatives have a characteristic spectrum which depends on their composition, the valence forces between the atoms in the molecule and the molecular symmetry or the arrangement of the atoms in space. This permits the identification of the components of hydrocarbon mixtures if the mixtures are not too complex. Even in the latter case it is possible to identify the type of hydrocarbons and their derivatives. The olefins, cycloolefins, acetylenes, and aromatic compounds have characteristic Raman frequencies depending on the ring structure and on the ethylenic and acetylenic type of linkage. The ethers, alcohols, and cyclic compounds may likewise be distinguished.

The principal utility of the Raman effect, however, rests in its application where other methods are either cumbersome or unavailing. It is possible, for example, to follow the fractional distillation of naturally occurring terpenes and to determine the presence of mixed isomers. The type and quantity of olefins occurring in cracked gasoline can also be estimated.

Apart from these purely chemical applications, information regarding bond strength, specific heats, and latent heats of fusion is made available from these spectroscopic data. It is shown that the determination of the molecular constitution of many complex organic compounds can best be made by means of Raman spectra.

- (954) The technique of securing undisturbed core-samples of the ocean bottom. Charles Snowden Piggot. *Proc. Amer. Phil. Soc.*, vol. 79, pp. 35-46 (1938).

A ten-minute address given as part of the "Symposium on the Geophysical Exploration of the Ocean Bottom," held at the Autumn General Meeting of the American Philosophical Society, Philadelphia, Pennsylvania, November 26, 1937.

Adequate sampling of the ocean bottom below more than 1000 fathoms becomes increasingly difficult with increasing depth. A sampling apparatus must take down with it the necessary energy. Such an apparatus is described and the technique of its successful manipulation below 2600 fathoms is discussed.

- (955) Uraninite and associated minerals from Haddam Neck, Connecticut. Earl Ingerson. *Amer. Mineral.*, vol. 23, pp. 269-276 (1938).

Torbernite has been known from the Rock Landing quarry at Haddam Neck, Connecticut, but uraninite from that locality has not been described. A recent find includes two large pieces ($6 \times 7 \times 10$ cm. and $2 \times 3 \times 4$ cm.) and numerous smaller fragments of uraninite. It was identified by its crystal form, etch tests, microchemical test for uranium, its radioactivity, and X-ray determination. An age determination by Hecht and Kroupa gives a value of about 285 million years. This is in good agreement with the results of analyses of minerals from other Connecticut pegmatites and places the time of formation as late Devonian.

Other minerals included in the find are gummite, autunite, torbernite, and columbite, besides the more common species smoky quartz, muscovite, potassium feldspar (perthite), black tourmaline, apatite, large beryl crystals, and small cubes of pyrite.

- (956) Rock formation: Nature's chemical industry. George W. Morey. *Chemistry and Industry*, vol. 57, pp. 966-971 (1938).

A lecture delivered before a joint meeting of the Society of Chemical Industry and the New York Section of the American Chemical Society, April 8, 1938.

- (957) Crystallization equilibrium in nepheline-albite-silica mixtures with fayalite. Norman L. Bowen and J. F. Schairer. *Jour. Geol.*, vol. 46, pp. 397-411 (1938).

This paper presents the results of a thermal study of the system, $\text{NaAlSi}_3\text{O}_8$ — FeO — SiO_2 , and discusses their application to petrology. The crystalline phases formed in the various compositions are cristobalite, tridymite, albite, fayalite, nepheline, carnegieite, hercynite, and wüstite. There are two ternary eutectics, one between tridymite, albite, and fayalite (temperature $980 \pm 10^\circ \text{C.}$) which may be regarded as a simplified fayalite rhyolite, and the other between nepheline, albite, and fayalite (temperature $990 \pm 10^\circ \text{C.}$) which may be regarded as a simplified fayalite phonolite. These and other findings are discussed in connection with the origin of natural phonolite, trachytes, and rhyolites carrying fayalite.

- (958) The concentration of the less familiar elements through igneous and related activity. E. G. Zies. *Chem. Rev.*, vol. 23, pp. 47-64 (1938).

The bulk of the Earth's crust is composed of igneous rocks, and with respect to its entirety the concentration of the less familiar elements is extremely low. They assume economic importance only when they have been reconcentrated in some favorable physico-chemical environment. Some attain this importance when through the various processes of magmatic differentiation they have accumulated in the mother liquor from which the pegmatites are derived and combine with other elements to form distinct minerals. It is quite probable that acid vapors are important at this stage of differentiation because the halides, sulfides, and even oxides of many of these elements are volatile at the prevailing temperatures. Considerable

evidence has been obtained that this type of concentration also takes place during volcanic activity. There is still another method by which a rare element can accumulate in a favorable environment. It can be segregated within the crystal lattice of some common mineral because its ionic radius is almost identical with that of one of the constituents in the mineral. This theory of "camouflage" was developed by V. M. Goldschmidt and is a useful guide for the analyst in searching for the rare and less familiar elements.

- (959) Laboratory technique of petrofabric analysis. Earl Ingerson. Part II of Memoir 6, Geol. Soc. Amer., "Structural petrology," by E. B. Knopf and Earl Ingerson, pp. 209-262 (1938).

The methods of fabric analysis are being used more and more in this country. They are now being taught in several universities as a part of structural geology, as extra-curricular series of lectures, or as independent courses.

There are several fragmentary accounts in English of the methods of fabric analysis, but to date no complete, fully illustrated account of the laboratory technique has appeared. This paper is an attempt to fill the need for such a manual. The various steps of the laboratory procedure are described and they are illustrated by photographs of specimens and apparatus, and by drawings. There are forty-eight illustrations.

The exhaustive study of a single specimen is described, but it is made clear that for most problems only a part of the complete procedure will be necessary. Simplifications are suggested.

The following chapter headings indicate the scope of the work: (1) Study of Hand Specimens, (2) Study of Thin and Polished Sections, (3) Universal Stage Technique, (4) Preparation of Petrofabric Diagrams, and (5) Rotation of Diagrams.

- (960) Contact relations between rhyolite and basalt on Gardiner River, Yellowstone Park. Clarence N. Fenner. Bull. Geol. Soc. Amer., vol. 49, pp. 1441-1484 (1938.).

In an area on Gardiner River, a flow of rhyolitic lava had followed a small valley previously eroded in a basaltic surface. Remarkable contact effects, apparently different in some respects from anything previously recorded, were produced.

In many places, the rhyolite has penetrated deeply into the basalt, as complex networks of veins and dike-like bodies, which ramify through the basalt in intricate patterns. Erosive action of the rhyolite flow upon the basaltic surface apparently brought about modifications of the original channel. The composition of the basalt near contacts was greatly changed. Basaltic constituents were carried away and rhyolitic constituents were substituted. Analyses show that the compositions lie almost exactly on straight lines between basalt and rhyolite.

The behavior of the rhyolite in producing these effects was far from what has been considered by many geologists as orthodox for such a magma, and in attempting to analyze the problems presented and find a reasonable explanation, it has seemed necessary to attribute properties to the rhyolite somewhat different from those usually postulated. In reaching conclusions, the field observations have been supplemented with the study of polished specimens and microscopic sections, and with chemical work. From all the information obtained, it seems most probable that the medium by which basaltic constituents were carried away was that of the vapors evolved from the rhyolite. Whatever the medium, the fact that large quantities were thus removed implies large stores of energy in some latent form in the rhyolitic magma. The rectilinear compositions of modified basalts indicate that all constituents of the original basalt were present in exactly the right proportions to satisfy the solution requirements of the rhyolitic medium. This, in turn, implies

some extraordinary, but unexplained, genetic relationship between the basalt and the rhyolite.

- (961) The properties of glass. George W. Morey. Amer. Chem. Soc. Monograph Series No. 77, 571 pp., 161 tables, 152 figs., New York, 1938. (Reinhold Publishing Corporation.)

Glass is a most important application of silicate science to technology, and the systematic and critical assembly and discussion of the properties of glass will be of service to silicate science in general, and in particular in its application to geology.

The properties of glass have long been of interest to the Geophysical Laboratory. In the first paper from the Laboratory, Day and Allen made observations on the absorption of heat in borax glass near its annealing range, which developed into an active international discussion of the nature and constitution of glass. The important work of Adams and Williamson on the annealing of glass, which laid the foundation for modern industrial practice, carried the problem farther, and the most recent contribution, on density and refractive index, gave us a more extensive knowledge of the variation of these properties with chemical composition in glasses than in other types of solutions. Studies from the Laboratory on the reaction between water and silicates established the theoretical principles underlying the chemical durability of glass. More recent studies on the phase equilibrium relations gave us for the first time a knowledge of the factor which made possible the manufacture of glass in its manifold applications to human needs.

The book is a comprehensive and critical discussion of the literature concerning the properties of glass, in which attempt has been made to include all measurements on glasses of known composition. Throughout, emphasis has been placed on physical properties as functions of chemical composition.

- (962) Summary of article by Bruno Sander: "Über Zusammenhänge zwischen Teilbewegung und Gefüge in Gesteinen," *Tschermak's mineralog. petrog. Mitt.*, vol. 30, pp. 281-314 (1911). Earl Ingerson. Excerpt from "Report of the Committee on Structural Petrology," Division of Geology and Geography, National Research Council, October, 1938, pp. 23-31.

This is the paper in which the fundamental concepts of petrofabrics were first published. The chief one of these is that during deformation rocks undergo a pervasive differential movement and that the deformation of the mass as a whole is the integration of the differential displacements along *s*-planes. These movements determine the rock fabric including even the orientation of the individual component mineral grains, so that the symmetry of the deforming movement is reflected in the symmetry of the fabric. Rocks that have undergone such pervasive differential movement are called *tectonites*; other rocks are *non-tectonites*.

Another important principle is that the original fabric of a rock determines in large measure what fabric will be impressed upon it by a given deformation. The renewed use of existing structure planes is operative in almost any deformation from microscopic structures to the largest tectonic features. Microscopic folds may guide later folding. Schistosity may be copied after an older structure (e.g. bedding), or it may be thought of as an inhomogeneity that is a pattern of the mechanical strain in the rock.

Several examples of folding are given and one is described in detail, with a diagram to show the relation of the quartz orientation to folding, and to the original structure of the rock.

True phyllites, produced by facsimile crystallization in an original *s*-plane, are contrasted with phyllonites, which are due to the working out of a set of *s*-planes to phyllitic completeness by differential motion in *s*.

A value of fabric studies is that they may be able to reveal the arrangement and magnitude of differential movements where stratigraphic criteria fail. In many rocks the horizons of movement can be established more surely than stratigraphic horizons.

(963) Surface-manifestations of volcanic activity. E. G. Zies. Trans. Amer. Geophys. Union, 19th annual meeting, pp. 10-23 (1938).

The salient features that characterize the forcible extrusion during volcanic activity of hot gases, fluids, and solids are discussed in this paper. Typical volcanic areas in Alaska, Central America, Java, and Bali are described and illustrated. Emphasis is placed on the desirability of studying more intensively than heretofore the fumarolic activity that frequently precedes a volcanic eruption. Attention is also directed to the fact that study restricted to surface-manifestations can hardly yield a satisfactory explanation of the causes of volcanic activity since an eruption is only the culmination of a long sequence of events that took place within the hearth of the volcano.

(964) High temperature and pressure phase-equilibria in the albite—water and orthoclase—water systems. Roy W. Goranson. Trans. Amer. Geophys. Union, 19th annual meeting, pp. 271-273 (1938).

Freezing-point curves in the three dimensional temperature-pressure-concentration space are given for the albite—water and orthoclase—water systems. The increase in solubility of water in the silicate melt with pressure lowers the freezing point, at first very rapidly but with diminishing effect as the pressure rises. The freezing-point curve may even have a minimum temperature above which pressure it would begin to rise in temperature. This rapid change in slope of the freezing-point curve between one and 2000 bars pressure is, in large measure, a result of the effect of pressure on the solubility of water in the silicate melt, as may be observed from the temperature-concentration projection of the freezing-point curve.

A maximum in pressure on the freezing-point curves does not exist for any of the rock-forming silicates investigated, and therefore pressures developed as a result of crystallization may become relatively enormous, perhaps exceeding 5000 bars.

(965) Some recent developments and applications of the Raman effect. James H. Hibben. Publ. Amer. Assoc. Adv. Sci., Symposium No. 7 on "Recent advances in chemical physics" (1938).

This paper outlines the most recent work carried out at the Geophysical Laboratory on the application of Raman spectra to chemical and physical problems and some typical examples of the results obtained elsewhere. In the field of inorganic chemistry the constitution of water and aqueous solutions is discussed. The spectral results show that water is not represented by the simple formula, H_2O , but has what may be termed a continuing structure throughout the liquid. This is demonstrable by the Raman lines which correspond to intermolecular vibrations and hindered rotation of the water molecules. This structure is affected by temperature and solutes. The homopolarity and ionization of inorganic compounds such as zinc chloride in solution, and the complete ionization of the more heteropolar magnesium chloride can be shown by the Raman spectra of these substances. The repression of ionization in some compounds by means of a common ion effect is likewise demonstrable.

The results obtained with sulphuric acid and fuming sulphuric acid (Chédin and Gopala Pai) indicate that the constitution of sulphuric acid is strongly modified by dilution and that sulphuric acid reacts with sulphur trioxide to produce pyrosulphuric acid. Nitric acid likewise changes its constitution from the ester form $HONO_2$,

on dilution, to a nitrate ion having a plane triangular configuration with the D_{3h} symmetry. When it is mixed with sulphur trioxide the nitric acid is dehydrated and nitrogen pentoxide is formed.

In the field of organic chemistry it is shown that there is a strong tendency toward hydrogen bonding with dicarboxylic acids and short-chained monocarboxylic acids. This accounts for the peculiar behavior of the carboxyl groups in these acids. Of particular interest to biochemistry is the unequivocal demonstration of the zwitter-ion theory of amino acids (Edsall). When a nitrogen atom is positively

charged the Raman shifts corresponding to the $\overset{+}{N}$ -H linkage differs from the ordinary N-H ones. This observation, together with the change in carbonyl frequency when the hydrogen of the carboxyl group is ionized, indicates that an

amino acid undergoes the following transformation: $H_2N-R-COOH \rightarrow H_3\overset{+}{N}-R-COO^-$.

In the presence of an acid the formula is: $H_3\overset{+}{N}-R-COOH$ and on neutralization with a base it becomes: $H_2N-R-COO^-$.

(966) The freezing-point—solubility curves of hydrates and other compounds under pressure. Leason H. Adams. Amer. Jour. Sci., vol. 35A, pp. 1-18 (1938).

For the determination of equilibrium in systems under high pressure there are two principal modes of attack. We may either devise an experimental method for measuring directly the solubility at the various pressures, or determine indirectly the variation of concentration with pressure under conditions of equilibrium by measuring the compressibilities of the several phases and applying a simple thermodynamic relation. In a previous communication from this Laboratory it was shown that in the study of simple systems under pressures of several thousand bars (metric atmospheres) the indirect thermodynamic method is convenient and precise. Equilibrium curves for systems in which hydrates and other compounds appear are now considered in detail and the various equations used in passing from volume-change measurements to points on the freezing-point—solubility curves are set forth, and concrete examples are given.

(967) Lavas of the African Rift Valleys and their tectonic setting. Norman L. Bowen. Amer. Jour. Sci., vol. 35A, pp. 19-33 (1938).

The state of knowledge and opinion as to the African Rift Valleys and their lavas was, a decade ago, such as to suggest that a definite correlation might be made between the tectonics and the chemistry of the lavas. The Western Rift Valley seemed to have been formed as a result of compressive stresses in the crust and to have associated with it lavas of potash-rich character. The Eastern Rift Valley seemed to have been formed as a result of tensional stresses and to have associated with it lavas of soda-rich character. The picture now presented is less simple. As a result of further investigation there has arisen much diversity of opinion as to the tectonic forces controlling the formation of both Rift Valleys, and there seems therefore no adequate basis for an attempt to correlate lava chemistry with contrasted tectonics. In addition, recent studies of the lavas have brought to light many exceptions to the general tendency towards preponderance of potash in the Western Rift and preponderance of soda in the Eastern Rift. Some new analyses are given which illustrate these exceptions and emphasize the fact that, as in the case of the tectonic relations, no simple picture of the chemistry of the lavas can be outlined at the present time. Indeed, when the question of the origin of the dominant lavas of the Western Rift is reviewed in the light of latest knowledge, their potash-rich character seems to be a relatively accidental circumstance. This

question is discussed and the lack of any convincing relation between lava chemistry and tectony in the Rift Valleys is emphasized.

(968) The phenomena of Falling Mountain. Clarence N. Fenner. *Amer. Jour. Sci.*, vol. 35A, pp. 35-48 (1938).

As a result of the eruptive activity in the Katmai region, Alaska, a large slice of a mountain was broken loose and collapsed into the valley. For many years afterward, the fractured scarp was the site of fumarolic activity. During the same period, boulders and masses of rock continued to be set free and drop off.

Prior to these events, the rock of the mountain appears to have been a rather siliceous, dense andesite, of normal appearance. The rocks that subsequently became loosened, and formed a talus, show interesting modifications. They have been penetrated with irregular channels of solution, and large quantities of tridymite have been deposited, together with cristobalite and hematite. Much mineral matter has been carried away. The close interrelationship of the various phenomena indicates that the removal of mineral matter, by which channels were formed, and the deposition of new minerals, were direct results of the action of the fumarolic vapors.

(969) On the effect of pressure on the solubility of solids in liquids. R. E. Gibson. *Amer. Jour. Sci.*, vol. 35A, pp. 49-69 (1938).

From an empirical analysis of the data concerning the effect of pressure on the solubility of solids in liquids, the volume changes and compressibilities of solutions, it is concluded that only in somewhat exceptional cases is the solubility of a solid in a liquid raised by pressure, a conclusion which is not novel. However, solutions of the carbonates, sulphates, sulphides, fluorides, and hydroxides of some alkalis, the alkaline earths, and the heavy metals in water, especially where the saturated solutions are very dilute, are definitely to be classed among these exceptional cases, and it is pointed out that the solubilities of these substances may be very significantly increased by pressures below 1000 atmospheres. It seems unlikely that the solubility of silicate minerals in molten silicates will be increased by pressure, and, indeed, the opposite effect is more to be expected, although the complications introduced by structural effects in these liquids render general statements quite risky.

The empirical arguments leading to these conclusions are given in some detail and especial emphasis is laid on the volume change which takes place when the liquid components are mixed, a quantity which at low pressures plays an important role in determining the piezo-chemical behavior of polycomponent systems and sometimes renders deductions based solely on the thermodynamic behavior of the pure components inapplicable to solutions. The effect of pressure on the solubility of solids is correlated qualitatively with the types of cohesive forces in the pure components and the solutions involved.

New data on the solubility of cesium bromide in water at pressures up to 1500 atmospheres and the partial volumes of sodium chlorides at 1 and 1000 bars pressure and at temperatures between 25 and 95° C. are also included.

(970) Silicate—water systems: Phase equilibria in the $\text{NaAlSi}_3\text{O}_8$ (albite)— H_2O and KAlSi_3O_8 (orthoclase)— H_2O systems at high temperatures and pressures. Roy W. Goranson. *Amer. Jour. Sci.*, vol. 35A, pp. 71-91 (1938).

This paper includes experimentally determined phase equilibrium relations for the albite—water and orthoclase—water systems from 800 to 1200° C. and pressures to 4000 bars and is a part of the series constituting a program of research on silicate—water systems begun some years ago by the writer.

The freezing-point curves of these systems extend out into three-dimensional temperature-pressure-concentration space and have been completed for albite—water.

The orthoclase—water system is somewhat more complex in that at low pressures, i.e. to about 2600 bars, orthoclase melts incongruently to leucite and liquid. The solubility of water in this liquid has not yet been determined as a function of temperature and pressure so that only the projection of the freezing-point curve on the temperature-pressure coordinate plane is given herein for the latter system.

In order to obtain other thermodynamic data such as apparent volumes and heats of evaporation it was necessary to obtain the temperature-pressure-volume relations of water in this region. These latter data are in large part extrapolated, consequently the derived thermodynamic quantities will have a lower degree of accuracy.

The data show that the pressures developed on crystallization may not only comply with but actually exceed the pressures necessary to explain certain volcanic phenomena.

(971) The system, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ (nephelite, carnegieite)— $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ (albite). J. W. Greig and Tom. F. W. Barth, *Amer. Jour. Sci.*, vol. 35A, pp. 93-112 (1938).

This paper presents the results of an experimental investigation of phase equilibrium relationships in the system, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ (nephelite, carnegieite)— $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ (albite), at atmospheric pressure, over a range of temperature of about 500° C., within which all the melting phenomena occur. The results are summarized and shown graphically in an equilibrium diagram, and the principal data, on which the diagram is based, are collected in tabular form. The relationships in this system, with albite as one end member, are similar to those found in the corresponding system, in which the place of albite is taken by anorthite, the other end member of the plagioclase series (N. L. Bowen, *Amer. Jour. Sci.*, vol. 33, pp. 551-573, 1912).

In view of the similarity of these two systems it is to be expected that closely similar relationships will be found to obtain between nephelite, carnegieite, and feldspar across the ternary system, nephelite, carnegieite—albite—anorthite, modified of course by the more complex nature of equilibrium in the ternary system. With the three binary systems known (N. L. Bowen, *op. cit.*; *Amer. Jour. Sci.*, vol. 35, pp. 577-599, 1913), and no intermediate compounds except jadeite known or to be expected, it is a simple matter to draw up a ternary diagram that, while not correct in detail, will show the general relationships. For the convenience of the reader such a diagram has been added.

Jadeites approach in composition the compound $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$ intermediate between the two end members of this system, but jadeites are not stable at the pressure and temperatures of the experiments so the compound does not appear on the equilibrium diagram. This is consistent with the conclusion arrived at by petrologists, from a study of natural occurrences, that jadeite is a high-pressure phase.

(972) The constitution of some boric oxide compounds. James H. Hibben. *Amer. Jour. Sci.*, vol. 35A pp. 113-125 (1938).

The constitution of boric acid and its salts was investigated in detail. From the Raman spectrum of boric acid it is concluded that this substance may be represented by a molecule of the general type AB_3 having the symmetry D_{3h} in which all the OH groups lie at the corner of a plane triangle with the boron atom in the center. There are probably some intermolecular binding forces. All the hydrogens are attached directly to oxygen atoms. Typical O-H Raman shifts are found in crystalline boric acid.

The BO_2 ion from sodium metaborate is found to possess a bent structure probably having the symmetry C_{2v} . The sodium salts of boric acid were found to yield, on solution, mixtures of sodium metaborate and boric acid. A stepwise neutraliza-

tion of boric acid with sodium hydroxide results in the immediate formation of the metaborate ion. The addition of a molal excess of hydrochloric acid to an aqueous solution made up of water and sodium tetraborate, $\text{Na}_2\text{B}_4\text{O}_7$, results in a complete conversion of the tetraborate to boric acid. All these changes are demonstrable by means of the Raman effect without altering in any way the solutions or their constituents.

The spectrum of crystalline sodium tetraborate is consistent with the view that the crystals are made up of long chains of boric oxide groups. The simplicity of the spectrum makes it seem doubtful that the crystalline tetraborate consists of ring compounds. The spectrum from borax glass is likewise simple, and it indicates the formation of the glass by the interlacing of BO_3 and BO_2 groups. The spectrum obtainable from a solution of the tetraborate does not differ widely from that of the crystalline compound.

The water of crystallization in the metaborate and tetraborate yields a number of fairly sharp water bands. There is one particularly strong and sharp O-H line in the tetrahydrate of the tetraborate.

(973) Albite trends in some rocks of the Piedmont. Earl Ingerson. *Amer. Jour. Sci.*, vol. 35A, pp. 127-141 (1938).

There are albite porphyroblasts in most of the rocks of the Piedmont province of southern Pennsylvania and northern Maryland. Many of these albite metacrysts show "trends," that is, they have inclusions that show pronounced alignments. These trends have been interpreted as relict structures indicative of older periods of metamorphism. The present work shows that the albite trends in the Port Deposit granodiorite complex and associated rocks are not relict structures but are controlled by the lattice of the feldspar grains. They were probably developed by late hydrothermal activity. This does not mean that there has been only one period of metamorphism affecting these rocks, but merely that the albite trends cannot be used as evidence for other periods of metamorphism. Similar studies from the literature are cited. In some of these, the trends appear to be true relict structures. In others, they are related solely to the lattice of the host feldspars.

(974) The system, water—boron oxide. F. C. Kracek, G. W. Morey, and H. E. Merwin. *Amer. Jour. Sci.*, vol. 35A, pp. 143-171 (1938).

The equilibrium diagram for the system of water and boron oxide has been established by measuring the solubility over the whole range of compositions.

The crystalline phases which occur in the system are ice, H_3BO_3 , three modifications of HBO_2 , which are monotropically related to each other, and crystalline B_2O_3 . Solubility relations have been determined for each of these phases.

The solubility curve for ice extends only from the melting point of ice to the cryohydric point at -0.76°C . The curve for H_3BO_3 rises smoothly from this point to a maximum at the melting point (metastable) of H_3BO_3 , 170.9°C . and then descends to end at the metastable eutectic for HBO_2III and H_3BO_3 .

The three forms of HBO_2 melt congruently: HBO_2I , the stable modification, at 236°C ., and HBO_2II and HBO_2III , both metastable, at 200.9°C . and 176.0°C ., respectively. Their solubility curves have flat maxima at the composition HBO_2 . The curve for the stable form, HBO_2I , intersects the curve for H_3BO_3 at 169°C ., at which point H_3BO_3 decomposes to form HBO_2I and a solution of the equilibrium composition. The reaction is an abnormally sluggish one, so that the metastable continuation of the solubility curve of H_3BO_3 is realized as if HBO_2I did not exist. The curves for HBO_2II and HBO_2III intersect that of H_3BO_3 at metastable eutectics located at 169.6°C . and 158.5°C ., in the order given.

Crystalline B_2O_3 melts at $450 \pm 2^\circ$ C. It has been crystallized from solution in sealed tubes, as well as in open vessels at atmospheric pressure, and various factors influencing its spontaneous growth have been established. The solubility curve for B_2O_3 extends from the melting point to the intersection with the curve of HBO_2 I at 235° C., and with that of HBO_2 II at 200° C. Both of these points are eutectics, the second being metastable. From the slope of the solubility curve the latent heat of fusion of B_2O_3 is calculated to be 97 cal./g.

P-T-X relations for the saturated solutions have been evaluated by combining the solubility data with deductions based on existing vapor pressure measurements. The resulting diagram, described in the text, brings out, among other things, the interesting fact that crystalline B_2O_3 can coexist with solutions at a vapor pressure of about 3 atmospheres in the neighborhood of 280° C. The oxide crystallizes relatively rapidly in sealed tubes in this region of temperature. The oxide crystallizes exceedingly slowly, on the other hand, from the nearly anhydrous melts of vitreous B_2O_3 , and never spontaneously in this region of composition. The spontaneous crystallization is initiated, in the more aqueous solutions, by the presence of HBO_2 I, but not by the presence of the other modifications of metaboric acid.

The crystallographic and optical properties of the new crystal phases were measured, and are described in detail in the text.

(975) The unit cell and space-group of β -glycine. C. J. Ksanda and G. Tunell. *Amer. Jour. Sci.*, vol. 35A, pp. 173-178 (1938).

Faceted crystals of β -glycine the identity of which was verified under the petrographic microscope by the immersion method were investigated by the equi-inclination Weissenberg method. The unit cell dimensions were found to be $a_0 = 5.07$ Å, $b_0 = 6.32$ Å, $c_0 = 5.37$ Å, all ± 0.01 Å, $\beta = 113^\circ 27' \pm 15'$. From the systematically missing spectra β -glycine crystallizes either in the space-group $C_{2h}^2-P2_1/m$ or in the space-group $C_2^2-P2_1$.

(976) Clays and other minerals from the deep sea, hot springs, and weathered rocks. H. E. Merwin and E. Posnjak. *Amer. Jour. Sci.*, vol. 35A, pp. 179-184 (1938).

X-rays and optical methods were used. Comparison materials, especially clays, required study. It was found desirable in the nomenclature of the optical properties of clays to take account of the differences in refractive index observed for some clays when immersed in different liquids. Staining was used to indicate the presence and the character of clays.

Some of the minerals observed in the bottom samples taken by the *Carnegie* were: dolomite, considered syngenetic; muscovite, considered residual; montmorillonite and phillipsite, syngenetic; and one unidentified iron-manganese mineral.

(977) Studies of solubility in systems containing alkali and water: I. General introduction. II. A filter autoclave for solubility measurements at elevated temperatures and atmospheric pressure. III. Solubility of NaOH in a saturated Na_2CO_3 solution between 60 and 70° C. George W. Morey and John S. Burlew. *Amer. Jour. Sci.*, vol. 35A, pp. 185-215 (1938).

The application of physico-chemical principles to the problems of pegmatite formation and the hydrothermal alteration of minerals requires knowledge of the solubility or fusion surface of the system, $Na_2O-K_2O-Al_2O_3-SiO_2-H_2O$, at temperatures below about 600° C. As a first step toward gaining this knowledge a new type of autoclave has been designed for solubility studies by the analytical method. With it a mixture of solid and liquid at a constant temperature can be stirred in a silver vessel and then filtered through a platinum felt, after which the filtrate is cooled and analyzed. Such an autoclave for use at atmospheric pressure has been perfected during investigation of part of the system, $NaOH-Na_2CO_3-H_2O$, at elevated

temperatures. The liquidus temperatures along the boundary curves $\text{NaOH} \cdot \text{H}_2\text{O}$ — Na_2CO_3 and NaOH — Na_2CO_3 between 60 and 70° are now reported, together with the optical properties of $\text{NaOH} \cdot \text{H}_2\text{O}$ and NaOH .

(978) The system, water—sodium disilicate. G. W. Morey and Earl Ingerson. *Amer. Jour. Sci.*, vol. 35A, pp. 217–225 (1938).

An apparatus has been constructed for studying the lowering of melting point of silicates when heated in steam at high pressures, and the results of a study of the system, water—sodium disilicate, are presented.

(979) Radium in rocks. V: The radium content of the four groups of pre-Cambrian granites of Finland. Charles Snowden Piggot. *Amer. Jour. Sci.*, vol. 35A, pp. 227–229 (1938).

The radium content of the pre-Cambrian granites of Finland is reported, grouped according to the four classifications of Sederholm.

(980) Radium and the petrology of certain granites of Finland. Tom. F. W. Barth. *Amer. Jour. Sci.*, vol. 35A, pp. 231–245 (1938).

The radium content of various types of granites of Finland is compared with certain petrologic characteristics of the several rocks. No relation is found between radium and potash or ferrous oxide, but for granites belonging to the same type the radium content can be correlated with the amount of biotite.

(981) The system, CaSO_4 — H_2O . E. Posnjak. *Amer. Jour. Sci.*, vol. 35A (1938).

Since the appearance many years ago of the investigation by van't Hoff and his associates on the various calcium sulphates and their relationships, which formed part of their classical work on the formation of the Stassfurt salt deposits, there has been an unending controversy regarding the true state of affairs in the system, CaSO_4 — H_2O . No attempt, however, is made to give a detailed review of this literature. After considering the facts which have been brought out, and checking experimentally some that seemed most pertinent, the present investigation found that the basis for most disagreements was some erroneous suppositions regarding phase relations involving hydrated compounds. These misled van't Hoff et al. to assume that a dissociation reaction took place when they found that under certain conditions anhydrite, and, as they thought, "soluble anhydrite" also, had crystallized in solutions at the expense of gypsum. As a result of this and the sluggishness of reaction in the case of the formation of hemihydrate, their data are erroneous.

Data brought out by various investigators, which are recounted in the text, furnish definite and reliable information regarding the system, CaSO_4 — H_2O , between 0 and 200°. The transition point, gypsum—anhydrite, lies at $42 \pm 1^\circ$, and that of gypsum—hemihydrate at $97 \pm 1^\circ$. In the region between these two temperatures, gypsum is truly metastable. The transition point for hemihydrate into "soluble anhydrite" (γ - CaSO_4) lies apparently at a high temperature, and, owing to the instability of the two phases, cannot be established. A monotropic relation exists between anhydrite (β - CaSO_4) and "soluble anhydrite" (γ - CaSO_4).

Regarding the geologically important question of the conditions under which anhydrite may be deposited at ordinary temperatures, available information indicates that a high concentration of salt solutions is not required, but that anhydrite may be deposited from relatively dilute solutions.

(982) Direct measurement of silicate heats of melting. Howard S. Roberts. *Amer. Jour. Sci.*, vol. 35A (1938).

The reluctance of most silicates to crystallize when once melted makes it difficult to obtain their heats of melting when using calorimeters operated at room tempera-

tures. It is here shown that with a suitable high-temperature calorimeter we may measure the energy actually absorbed by the silicate in the act of melting, as is often done at low temperatures, and so obtain data of usable precision. Determinations are described using pure K_2SO_4 and somewhat impure Na_2SiO_3 whose melting points are 1069° and 1089° respectively.

(983) The system, leucite—diopside—silica. J. F. Schairer and N. L. Bowen. *Amer. Jour. Sci.*, vol. 35A (1938).

Several silicate systems have been investigated or are now being studied to ascertain what compositions residual liquids from fractional crystallization approach. This system combines the simple pyroxene, diopside, with potash-alumina silicates. Phase equilibrium data show that diopside is almost quantitatively removed, leaving liquids almost free from the pyroxene molecule.

Melting data for the system, leucite—diopside—silica, are presented by means of tables and a ternary diagram. There are no ternary compounds. There are two ternary invariant points, one a reaction point and the other a ternary eutectic. The field of diopside occupies a large part of the ternary diagram, and with mixtures containing even less than two per cent diopside in their total composition, diopside appears as the primary phase. On fractional crystallization, residual liquids approach in composition a mixture of potash feldspar and silica. A diagram showing the indices of refraction of ternary glasses is given, and also a preliminary diagram for the binary system, leucite—silica.

(984) The gases in rocks and some related problems. E. S. Shepherd. *Amer. Jour. Sci.*, vol. 35A (1938).

From the analysis of Kilauea gases collected in vacuum tubes the study was extended to those gases still retained by freshly collected lavas from Kilauea and other volcanoes. Later the work included gases from typical plutonics obtained by exhausting such rocks in vacuo. In the latter case it was found that careful selection of the material was needful and the geological implications of "alteration" were set forth. Studies of obsidians with varying amounts of water in solution revealed some important physical properties due to their water content, and the relation of these to the mechanism of lava flows in general is emphasized.

(985) Evidence on the intrusion-temperature of peridotites. Robert B. Sosman. *Amer. Jour. Sci.*, vol. 35A (1938).

Experiments in heating a coke inclusion from a peridotite dike in Fayette County, Pennsylvania, and chemical analyses of the same inclusion for hydrogen, oxygen, and nitrogen, agree in indicating that the maximum temperature reached by the coke was between 440 and $520^\circ C$. The intrusion-temperature of the peridotite could hardly have exceeded 600° . How a rock of peridotitic composition could have been intruded at so low a temperature remains to be determined by laboratory experiment.

(986) The crystallography of potassium tetrathionate. G. Tunell, H. E. Merwin, and C. J. Ksanda. *Amer. Jour. Sci.*, vol. 35A (1938).

Analyzed artificial crystals of potassium tetrathionate were measured on the two-circle reflection goniometer and their geometrical constants were calculated. The dimensions of the structural unit cell were determined by means of equi-inclination Weissenberg photographs to be $a_0 = 22.05\text{\AA}$, $b_0 = 7.99\text{\AA}$, $c_0 = 10.09\text{\AA}$, all $\pm 0.02\text{\AA}$, $\beta = 102^\circ 05' \pm 15'$. From the systematically absent spectra, the crystal habit, and the presence of pyro-electric and piezo-electric effects, the space-group of potassium tetrathionate is $C_{2h}^4 - Cc$. The refractive indices and their dispersion

were determined by the method of minimum deviation, and the optical orientation was established.

- (987) An improved torsion gravity meter. F. E. Wright and J. L. England. *Amer. Jour. Sci.*, vol. 35A (1938).

In the improved instrument, recently built at the Geophysical Laboratory, the torsion element is the same as that used heretofore; but its other parts have been rearranged to provide simpler control for operation in the field. The present apparatus is lighter than its predecessor and gives promise of even better field performance. The old instrument during its last period of eight months' service in occupying and reoccupying old and new gravity stations yielded results that, for any given station, agreed within one milligal. The new instrument is mounted inside a covered insulated motor truck; under ordinary conditions twenty or more stations per day can be occupied by the apparatus.

- (988) The concentration of the less familiar elements through igneous and related activity. E. G. Zies. *Amer. Jour. Sci.*, vol. 35A (1938).

Reprint, with slight modifications, of No. 958.

- (989) The Earth's interior: Its nature and composition. Leason H. Adams. *Smithsonian Report for 1937*, pp. 255-268. Published 1938.

Reprint, with slight modifications, of No. 921.

- (990) Annual Report for 1937-1938.

DIVISION OF HISTORICAL RESEARCH¹

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America, and the Pueblo area of southwestern United States. The Section of Post-Columbian American History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

It is the policy of the Division that no new unit of research shall be undertaken until at least the factual results of previous activities in the field concerned have been made of record. A large share of the Division's energies, during the past year, has accordingly been devoted to the working up of accumulated data and the writing of reports. This has served to direct special attention to problems of publication.

In general, first class factual literature in the social sciences and the humanities is pitifully scanty. In these, as in the natural sciences, the collection and the setting forth of data must precede synthesis and the drawing of conclusions. And because of the bewilderingly faceted life of man and the infinitely wide range of man's doings throughout the ages, in every conceivable type of historical setting, and in all possible sorts of physical environments, the human record must, for the present at least, be largely descriptive. Expression by formula is not feasible, nor can there often be used the condensed forms appropriate for exposition of the regularly repeating phenomena of biology. Publication, therefore, even in the case of the relatively small group of studies with which the Division is occupied, is inevitably voluminous; archaeological papers must carry a great amount of illustration. Costs, accordingly, are bound to be heavy; but, on the other hand, it is only fair to point out that acquisition of most anthropological and historical materials is relatively inexpensive, there being little or no call for physical equipment, for laboratories or instruments. However, neither need for much publication nor cheapness of fact finding justifies waste. Also, from the point of view of utility, it is essential that results be thoroughly digested and succinctly stated.

Because of the vast increase in scientific writing of all sorts, as well as because of the rapidly mounting costs of printing, it is certain that present methods for dissemination of knowledge will have to be rather drastically overhauled, those of the disciplines concerning man perhaps most severely of all. How this may be brought about, in the case of its own product, is being given anxious consideration by the Division. Those of its reports which are now well along in preparation will be submitted in forms sanctioned by previous practice. But it is probable that current studies of the

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situation will result in recommendations looking toward much simplified presentations and considerable reduction in manufacturing costs.

SECTION OF ABORIGINAL AMERICAN HISTORY

The work of the Section in the Maya field consists of archæological excavation, exploration, and the comparative study of certain particularly important aspects of Maya culture, such as the hieroglyphs, architecture, sculpture, and pottery. The Section also sponsors research in ethnology and linguistics, and cooperates with other agencies in biological, geological, and other studies designed to throw light on the environment in which the pre-Columbian Maya developed their remarkable civilization, and in which their descendants live today side by side with their Spanish conquerors. Workers in the Sections of Post-Columbian American History and the History of Science, carrying forward investigations in their own fields, add to the large body of information being accumulated in regard to the Maya.

As has already been stated, much of the time of the Division staff has, during the period under review, been spent in making the above information available through the writing of reports. Outstanding among several manuscripts so brought to completion are those of Dr. Morley, who has in press his compendious monograph on the hieroglyphic inscriptions of the ruined Maya cities of Peten, the fruit of over twenty years of study; and of Mr. Morris, whose report, embodying the results of his equally long-continued investigations in the very important Basket Maker and Pueblo sites of northern New Mexico and adjacent regions, is ready for the printer. These two monographs will always rank as fundamentally significant contributions to the literature of their respective fields. Progress in working up the results of other activities is noted below.

Uaxactun. Excavation at Uaxactun, in the Department of the Peten, Guatemala, was discontinued in the spring of 1937. This apparently oldest of First Empire Maya cities was under investigation for no less than eleven seasons. Findings of the first years have been recorded by Dr. and Mrs. Ricketson in a volume recently issued.¹ The six years 1932-1937 were largely devoted to study of the so-called "Palace," a multi-chambered structure which grew by accretion through a long period of time, and whose thorough dissection by A. L. Smith yielded extremely valuable data upon architectural development and the succession of pottery types. Mr. Smith and E. M. Shook, his associate during most of the work on the Palace, have been engaged, since the close of work at Uaxactun, in preparing the final report upon the general archæology of the site; while R. E. Smith, assisted by Mrs. Smith, has been studying and writing up, at the Institution's laboratory in Guatemala City, the enormous ceramic collections made at Uaxactun. It is believed that at least eighteen months more will be required for completion of these two papers.

Kaminal-juyu. The Chairman's excavations in the mounds and tombs of Kaminal-juyu, near Guatemala City, were also discontinued in 1937.

¹Uaxactun, Guatemala, Group E, 1926-1931. Carnegie Inst. Wash. Pub. No. 477 (September 1937).

The collections, particularly the pottery, throw much light upon the chronological relations between the cultures of the Guatemala highlands, those of the Maya First Empire in Peten, and those of central Mexico. Owing to collapse of the roofs of the tombs, the pottery accompanying the interments was badly broken and crushed. The difficult task of repairing the more than two hundred vessels, many of great beauty, and for the most part of types hitherto unknown, was carried out by Mr. Paul Richard of the American Museum of Natural History and Mrs. Harriet S. Cosgrove of the Peabody Museum of Harvard University, whose invaluable services were most generously made available to Carnegie Institution by Dr. Clark Wissler and Mr. Donald Scott, directors of the above museums. The skill of Mr. Richard and Mrs. Cosgrove served to put the pottery in shape for study, and for permanent exhibition in the National Museum of Guatemala, where it has now been deposited. Each piece was photographed by Miss Barbara Kidder and all outstanding pieces were reproduced in black and white or in water color by the Section's artists, Señores Antonio Tejeda and Victor Lucas. The Chairman spent the winter at the Guatemala laboratory, making notes on the pottery and other artifacts and on the specimens, other than ceramic, from Uaxactun. Mrs. Kidder, who, from the beginning of the Kaminal-juyu operations in 1935, has cared for and catalogued the collections, made, this year, a special study of the large number of jades found in the tombs.

Guatemala Office. In addition to routine archæological activities, the Guatemala Office, under direction of R. E. Smith, has continued to serve as local headquarters for research workers and visitors from several other institutions: Jeffries Wyman, biologist of the Museum of Comparative Zoology at Harvard; Linton Satterthwaite and J. Alden Mason, archæologists of the University of Pennsylvania Museum; Theodor Dobzhansky, geneticist of the California Institute of Technology and Carnegie Institution; J. Andrews King, ornithologist of the Field Museum of Natural History; and L. C. Stuart, herpetologist of the University of Michigan. By supplying information, making advance arrangements, securing necessary permits, and attending to the importation of supplies and the exportation of collections, the office is in position greatly to facilitate the work of the scientists who come to Guatemala for special investigations. The Division and Guatemala offices have also made available to the Shell Oil Company and the Fairchild Company all data in their possession regarding the Department of the Peten, where those organizations are carrying on geological and air-photographic surveys, the results of which will be of much value for the study of Maya archæology.

Architectural survey. During the past several years, Dr. H. E. D. Pollock has been engaged in architectural research in northern Yucatan; a field so large and so rich in remains that it has seemed best to treat it by chronological and topographic units. The important area of the Puuc, containing the most abundant and most representative ruins of the so-called "Maya renaissance," has now been explored and Dr. Pollock has devoted as much time as could be spared from his organization of the Section's photographic files (see p. 140) to preparing a report upon them. It is hoped that in this

paper methods can be developed for a briefer and more effective presentation of architectural data than has hitherto been attained.

Archæology of British Honduras. Mr. J. E. Thompson's work at the ruins of San José was begun as a joint project with Field Museum and completed by Carnegie Institution in 1936. San José, a small site, occupied from before the rise of the First Empire to a period apparently only shortly antedating the advent of Mexican influence in Yucatan, is important because it well exemplifies the minor communities, of which great numbers existed, and which must have formed the backbone, so to speak, of the Maya commonwealth, but which have hitherto largely been neglected by archæologists in favor of the larger, more spectacular cities. Its long occupation also rendered it an unusually favorable place for study of ceramic development. Mr. Thompson has divided his time during the past eighteen months between glyphic research and the study and preparation for publication of the archæological materials from San José. His report on the latter is now in press. He also made a short field trip to British Honduras during the winter of 1938 (see p. 152).

Geographical study. Information regarding the physical features of the Maya area, its geology, topography, climate, is scattered through a great number of publications: narratives of the Conquest, books of travel, scientific periodicals, government reports. In order to render this indispensable but now relatively inaccessible material available, Dr. O. G. Ricketson, Jr., is making a thorough search of the literature, is preparing an annotated bibliography, and is gathering notes for a general work upon the geography of southern Mexico and northern Central America, suitable for the use of the archæologist, the ethnologist, and the historian.

Photographic files. During the quarter-century of the Institution's work in the Maya field there have been accumulated more than 20,000 photographic negatives. These constitute the basic record of every excavation and exploration carried out by the Section. In the early years each investigator assumed charge of the photographs dealing with his own branch of the work. As the Maya project grew, however, it became obvious that a central repository must be established for the safe-keeping and adequate cataloguing of these pictures. A consolidated file was begun at the Section's former administrative office in Washington, but not until general headquarters were established did it become possible to assemble all the material and to secure from the hitherto scattered members of the staff the identifications necessary for accurate labeling.

In 1935 a new uniform system of field recording of photographs was put into operation by Dr. Pollock and during the past two years he has brought order into the great mass of older pictures. With the help of Miss Ritchie his reorganization of the file is now approaching completion. Negatives, contained in fireproof cases, are arranged serially by years; prints, mounted on cards and bearing negative number and identifying description, constitute a second series in which the photographs are grouped for ready reference by sites and subgrouped in such a way as to bring together all data upon individual buildings, stelæ, pottery, etc.

The foregoing activities indicate how large a proportion of the time of the Section's staff was spent, in 1937 and 1938, in laboratory work and in writing. In spite of this, several field projects were undertaken. Summary accounts are appended.¹

CHICHEN ITZA—S. G. MORLEY

The Chichen Itza Project of the Carnegie Institution of Washington began its fifteenth year in January. Dr. and Mrs. Morley reached Yucatan by way of Mexico City on December 28, and Messrs. E. T. P. Kennedy, R. T. Patton, J. H. Denison, Jr., and W. E. Shepherd (the last two, members of the Fifth Campeche Expedition) on January 6. Mr. Karl Ruppert, Director of the Fifth Campeche Expedition, reached Yucatan by way of Mexico City at the end of January and the expedition left Merida for central Campeche at the end of February, returning therefrom early in April.

Dr. Morley devoted the first six months of the year to correcting proof on his coming monograph on "The Inscriptions of Peten." The galley proof was completed and the first two volumes of page proof before he sailed for Europe on June 28 by way of Vera Cruz to attend the sessions of the Second International Congress of the Anthropological and Ethnological Sciences held at Copenhagen, Denmark, from August 1 to 6. In addition to representing the Institution at this congress he was also a member of the United States Government delegation thereto. He presented two papers: "A Review of Twenty-five Years' Research in the Maya Area of Middle America by the Carnegie Institution of Washington, 1914-1938" and "The Rise and Fall of the Maya Old Empire as Established by the Hieroglyphic Inscriptions."

The most important activity under the Chichen Itza Project during the current year, except the Fifth Campeche Expedition described elsewhere, was the survey of the ruins of Mayapan in northern central Yucatan, made by Mr. R. T. Patton, the expenses of which were defrayed partly by Mr. Patton himself, Mr. Percy Jackson, and Colonel F. Marion Barker, and partly by the Institution.

This survey was undertaken because the archæological importance of Mayapan as indicated by the brief descriptions of Stephens, Brasseur de Bourbourg, and later visitors, including several of the Institution's staff, appeared to be far less than its political preeminence in the thirteenth, fourteenth, and fifteenth centuries, as established by the Spanish and native chroniclers, would have demanded. The early authorities describe the site as walled, but although Stephens saw a section of the wall, nothing was known of its extent.

The Institution's survey establishes that the wall surrounding Mayapan is $5\frac{1}{2}$ miles in circuit, enclosing a rough oval about 2 square miles in area. The wall is made of dry-laid, irregular blocks of limestone, not dressed, with a very slight batter on both sides. The wall varies from 9 to 12 feet in thickness at the base and from 6 to 7 feet in height outside. There was formerly a low parapet along the outer edge of the wall, though in most places this has now fallen. There are several stairways on the inside leading to the top.

¹ See also p. 170 for a progress report upon Dr. Pogo's research in Maya astronomy, and p. 166 for statements regarding investigations in the documentary history of the Maya area.

Nine entrances, irregularly distributed and ranging in width from 3 to 6 feet, give access to the walled area. This number was of considerable importance, being that of the gods of the nine underworlds of Maya mythology, each one of which may have presided over one of the nine gates of the site.

The principal pyramids and mounds as well as the stelæ are concentrated near the center of the walled oval area. This central section was divided into squares of 200 meters on a side and surveyed, all constructions being exactly located. The principal axes of the central area were projected until they intersected the wall, and the central area tied thereto in four places. Finally, the 5½-mile circuit of the wall was surveyed by means of lines of sight just inside cut through the thick bush.

The constructions consist of pyramids, platforms, colonnades with drum columns, corbel-arched buildings, and four round towers, possibly astronomical, only one of which had been previously reported. There is little dressed masonry, surfacing for the most part having been effected by stuccoing. The architecture is far inferior to that of the other great cities of northern Yucatan—Chichen Itza, Uxmal, and those of the Puuc and Chenes regions. It more closely resembles that of the relatively late site of Tulum on the east coast of Yucatan; the latter is also the only other walled site known in the Maya area. These several points indicate that Mayapan rose to political preeminence at a relatively late period in Yucatan history, probably not until the twelfth or thirteenth century.

Nineteen *cenotes* were found within the walled area, for all of which, except two, native Maya names were obtained.

Eleven stelæ were located, nine sculptured and two dressed but plain. At the time Mayapan flourished Initial Series dating had been replaced throughout the Maya area by Period Ending dating, a method which, although not nearly so accurate as the Initial Series, served nevertheless to distinguish one katun or 20-year period from another within a period of two and a half centuries. Three Period Ending dates were deciphered by the writer on Mayapan monuments: Stela 1, Katun 10 Ahau, A.D. 1185, probably 10.18.0.0.0 10 Ahau 3 Tzec; Stela 5, Katun 4 Ahau, A.D. 1244, probably 11.1.0.0.0 4 Ahau 8 Mol; Stela 6, Katun 13 Ahau, A.D. 1283, probably 11.3.0.0.0 13 Ahau 13 Pax.

The results of this survey indicate that although Mayapan reached a position of first importance only at the close of Maya history when architectural decadence was well under way, its size satisfactorily agrees with the political preeminence ascribed to it by both the native and the Spanish chroniclers.

An epigraphic discovery of importance made by Mr. Alfonso Villa R. on a trip to the highlands of Chiapas, Mexico, in connection with the Ethnological and Sociological Survey should be mentioned here. He reports for the first time a monument from Tila, to which the designation Stela C has been given. This records both as an Initial Series and as a Period Ending the date 9.13.0.0.0 8 Ahau 8 Uo in bar and dot numerals.

Dr. Morris Steggerda of the Department of Genetics was at Chichen Itza for the eighth season in connection with his anthropometric, ethnological, and sociological studies. His experimental *milpa* is now entering its fifth year, and this protracted investigation of corn cultivation as practiced by

the modern Maya is proving one of the most fundamental studies made by the Institution in the Maya field.

As usual the Institution's headquarters at Chichen Itza were again utilized by investigators of other organizations. M. André Remondet, winner of the Grand Prix de Rome in 1937, having elected Maya architecture as his field for special study, spent three months at Chichen Itza in the winter and early spring making measured drawings, ground plans, and elevations of some of the more important buildings: the Castillo, the Mercado, the Vapor Bath, and the Temple of the Three Lintels. These drawings together with a wash drawing of the last were exhibited in the French Academy at Rome during May.

During June Dr. and Mrs. C. L. Lundell of the Herbarium of the University of Michigan were at Chichen Itza collecting botanical specimens in connection with the former's study of the botany of the Yucatan Peninsula. In July they spent three weeks collecting at Coba in northeastern Yucatan, using the Institution's camp equipment from Chichen Itza and taking with them as assistants several Maya from the neighboring village of Pisté, who have been working for the Institution in Yucatan during the past fifteen field seasons. The month of August was devoted to collecting in the northwestern part of Yucatan near Merida and the ecologically important northwest coast region.

THE 1938 BOTANICAL EXPEDITION TO YUCATAN AND QUINTANA ROO, MEXICO—C. L. LUNDELL

In continuation of the biological survey of the Maya area, under the joint auspices of the University of Michigan and the Carnegie Institution of Washington, botanical investigations were undertaken in Yucatan and Quintana Roo, Mexico, from May 27 through August 3, 1938, by the writer, and Amelia A. Lundell, who served as field assistant. The expedition, supported by the Horace H. Rackham School of Graduate Studies, and the Faculty Research Fund, University of Michigan, carried out intensive explorations in the coastal area forty miles east and west of Progreso, around Chichen Itza for a radius of twenty miles, and in the vicinity of Coba, Quintana Roo. Important but smaller collections were made along the road south to Uxmal and around Merida. Facilities of the Carnegie Institution of Washington at Chichen Itza, generously placed at the disposal of the expedition, contributed substantially to the success of the field work.

The State of Yucatan has been worked more extensively by resident collectors and visiting botanists than any other part of the Yucatan Peninsula, yet few data have been gathered concerning such important subjects as the general aspects of the vegetation, zonation, abundance and distribution of species, successional stages, relic forest areas and their importance in the interpretation of the natural climatic climax forest. Biotic influences, which include the effect of *milpa* agriculture and fire destruction, have been largely ignored. Hence these subjects were given primary consideration. In the course of the studies, approximately 8000 herbarium specimens were collected, included among which are adequate series of such difficult groups

as cacti and palms. Many of the described endemics, some known from single collections without locality data, were rediscovered and gathered repeatedly with both flowers and fruits. A few species, some characteristic of the Yucatan and Quintana Roo forests, appear to be new to science. Clearer taxonomic interpretation of a number of species and some genera, heretofore inadequately known, will now be possible from the ample herbarium material obtained. To substantiate and amplify ethnobotanical data, this subject received special attention in the Chichen Itza area with the able assistance of Mr. Francisco Campos, who served as our interrogator of Maya herb doctors and farmers. The extensive collections from Coba, the first large series from the interior of Quintana Roo, reveal an astonishingly close floristic and physiognomic relationship between the east coast forest and the older forest of Yucatan. Collections of reptiles and amphibians from Chichen Itza and Coba, and fish from Lake Coba and Lake Macanxoc, Quintana Roo, were made incidentally to the botanical work.

It is premature to describe the vegetation of Yucatan and Quintana Roo before the collections have been identified and the extensive field notes critically analyzed, hence the following preliminary discussions should be considered tentative and subject to revision.

The dry coastal area, east and west of Progreso, consists of three distinct physiographic zones: (1) the sand dunes lying between the sea and the *cienaga*; (2) the shallow *cienaga* and salt flats; and (3) the limestone flats extending for about ten miles south from the edge of the *cienaga* into the interior.

The sand dunes, in areas remote from the coastal settlements, support low thickets ranging up to 15 feet in height. Around Progreso and other villages, cutting for wood, charcoal, and other needs keeps the vegetation down so that it scarcely exceeds 5 feet even in the most favorable spots. The abundant treelets and shrubs of the dunes include species in the following genera: *Metopium*, *Coccoloba*, *Thrinax*, *Coccothrinax*, *Hippocratea*, *Maytenus*, *Bumelia*, *Capparis*, *Lycium*, *Agave*, *Jacquinia*, *Rhacoma*, *Thevetia*, *Cæsalpinia*, *Cordia*, *Tournefortia*, and *Gymnopodium*. Cacti are locally abundant, but nowhere as common as in the area south of the *cienaga*. Of particular interest is the occurrence on the sand dunes, as shrubs or gnarled treelets, of such species as *Achras Zapota*, *Krugiodendron ferreum*, *Thevetia peruviana*, and *Metopium Brownei*, all of which are large trees in the wet forest to the south.

The *cienaga*, a shallow salt-water swamp behind the dunes, has wide areas of open water with islands of mangrove. The bordering flats usually are covered with mangrove, or in open areas with *Salicornia*, *Batis*, and other halophytic herbs.

From the southern edge of the *cienaga* low limestone flats, interspersed with rainy-season ponds, have a distinctive vegetation which extends inland for approximately ten miles in the Progreso region. Because of the high percentage of endemics and the predominance of cacti, this xerophytic belt, where rainfall does not exceed 20 inches, is one of the most interesting phytogeographical areas in the peninsula. The vegetation reaches a height of 45 feet in undisturbed sections, but averages much less in the proximity of vil-

lages owing to culling and clearing. The large cacti, *Nopalea Gaumeri*, *N. inaperta*, *Pachycereus Gaumeri*, *Lemaireocereus griseus*, and *Cephalocereus Gaumeri*, are abundant, forming almost impenetrable thickets in undisturbed sections. Low cacti, *Opuntia Dillenii*, *Acanthocereus pentagonus*, and several other species, not identified, are locally conspicuous. The interesting low species of *Neomammillaria* abound here only. Species in the following genera are the principal associates of the cacti: *Acacia*, *Mimosa*, *Pedilanthus*, *Agave*, *Hæmatoxylum*, *Euphorbia*, *Prosopis*, *Zanthoxylum*, *Pithecolobium*, and *Croton*.

Inland from the cactus thicket zone, the limestone plain rises slightly, extending unbroken southward to the low sierras bordering Yucatan on the south and southwest. With increase of rainfall from the coast inland, the vegetation undergoes a marked transition, although this transition is masked by invasion of species from the dry cactus zone, a result of biotic disturbances. The greater part of the State of Yucatan, not planted in henequen or cleared for *milpas*, is covered with low thickets from 10 to 25 feet in height. These are all second growth, the result of repeated clearing and fire destruction. Two species of legumes, *Acacia Gaumeri* and *Mimosa hemiendyta*, both native to the peninsula, are the principal dominants, with a host of shrubs and vines as associates. This widespread assemblage, often considered to be the typical vegetation of Yucatan, is nothing more than an early successional stage.

In a country which has supported as large an Indian population as Yucatan, thinly settled outlying districts are likely to contain the only sections of forest little disturbed by man. In the search for data with which to reconstruct the appearance of the old climax vegetation of Yucatan, borderline country, far from villages and outside the limits usually reached by *milperos*, was combed. Here stands of advanced forest, with relics of *Achras Zapota* and other slow-growing hardwoods, were discovered.

The floristic composition and physiognomy of the advanced and relic forest stand out in marked contrast against the widespread young legume thickets. The height usually exceeds 50 feet. Species rare in the young thickets are here abundant, whereas *Acacia Gaumeri*, *Mimosa hemiendyta*, and other associates of the low rank growth are comparatively rare. Principal trees of the advanced and relic hardwood forest include the following: *Lysiloma bahamense*, *Vitex Gaumeri*, *Metopium Brownei*, *Piscidia* sp., *Suartzia* sp., *Lonchocarpus* spp., *Achras Zapota*, *Coccoloba* spp., *Bursera Simaruba*, *Cæsalpinia* spp., *Thouinia paucidentata*, *Torrubia* sp., *Hippocratea* sp., *Albizia* sp., *Guettarda Combsii*, *Byrsonima bucidæfolia*, and *Malmea* sp. Of the tall shrubs, the following are abundant: *Gymnopodium* sp., *Neomillspaughia* sp., *Diospyros* spp., *Eugenia* spp., *Acalypha* spp., *Croton* spp., *Hampea trilobata*, *Randia* spp., *Erythroxylon* spp., and *Bauhinia* spp.

The most extensive remnants of the old forest were found in the vicinity of Yokdzonoot between the villages of Piste and Libre Union, and along the road from Chichen Itza to Kaua. Scattered stands of old second growth along the road from Merida to Uxmal have much the same assemblage of species. The relic forest east of Coba, Quintana Roo likewise resembles

the advanced forest near Yokdzonoot and along the Kausa road; in fact, the stands at Coba differ little floristically, and the dominants are the same. We may conclude that similar forest probably extended at one time as a wide belt across the northern tip of the peninsula, possibly as far south as Peto and Champoton. Its southern extension along the east coast is not known.

Throughout this zone, endemics outnumber in individuals all other species, therefore comprise the bulk of the forest mass. In 1936 a similar condition was observed in advanced forest on the limestone plateau of southern British Honduras.

The older forest of Yucatan, deciduous with few exceptions during the dry season, may be designated as advanced deciduous forest to distinguish it from the advanced, predominantly evergreen quasi-rain forest of southern Campeche, southern Quintana Roo, northern Peten, and northern British Honduras.

This advanced forest of Yucatan and northern Quintana Roo differs considerably in dominance and to a certain degree floristically from the southern quasi-rain forest. Of significance is the absence in the north of such typical southern species as the *escoba* palm, *Cryosophila argentea*. The distribution of species in such genera as *Gymnopodium*, *Neomillspaughia*, *Diospyros*, *Cryosophila*, *Acacia*, *Mimosa*, *Orbignya*, and *Swietenia* must be studied to obtain satisfactory data by which these two phytogeographical areas may be more accurately delimited.

In spite of the fact that the relic forest east of Coba differs considerably from advanced forest in the vicinity of Old Empire ruins in southern Campeche and northern Peten, the forest covering the ruins of Coba compares very favorably with forest covering such sites as Calakmul, Topoxte, Naachtun, and Yaxha. On the Coba ruins, *Brosimum Alicastrum* dominates, with the following associates much in evidence: *Achras Zapota*, *Cedrela mexicana*, *Talisia olivæformis*, *Sabal* sp., *Protium Copal*, *Thevetia peruviana*, and *Chlorophora tinctoria*. All these are important in the economy of the Maya. Of interest is the prominence of *Chlorophora tinctoria* and *Thevetia peruviana*, both of which occur as trees up to 10 and 16 inches respectively in diameter. Neither one has been observed on Old Empire sites heretofore. An orange grove of undetermined age was discovered in a plaza growing in the shade of high *ramon* forest. Could this grove be a relic from Conquest times?

The rôle of fire in the destruction of tropical forest is nowhere more evident than in areas of Quintana Roo visited. Beyond the village of Dzitnup, along the trail to Coba, we rode for four hours through utterly desolated country. For at least six years, possibly longer, annual dry-season fires have swept through. In some places a few scattered large relic trees, *Vitex Gaumeri*, *Metopium Brownei*, and *Piscidia* sp., all noted for their fire resistance, still stand, which indicates that high forest covered the area previously, a fact attested to by Indians in Dzitnup. In some sections, not a living plant remained from the former forest, only fallen trees and standing skeletons. Not only has the forest been killed, but the destruction of the humus and roots by fire has resulted in complete erosion of the thin mantle

of soil into underground crevices to leave barren stretches of white pitted limestone.

Approaching the ruins of Coba, a section has escaped the fires for possibly two years. Here the rank second growth consists mainly of cecropias, acalyphas, and morning glory vines. East of Coba, fire destruction has not been as severe; the forest there, as already pointed out, resembles remnants of old Yucatan forest. The area of fire-culled forest is said by *chicleros* to extend unbroken almost to Tancah on the east coast.

Fire destruction has been repeatedly emphasized as one of the primary controlling factors to be considered in the interpretation of the vegetation of the Yucatan Peninsula.¹ Failure to recognize its extent and importance is due probably to confusion of rank second growth with old hardwood forest. The desolate area between the village of Dzitnup and Coba is a convincing demonstration of the widespread destructiveness of tropical forest fires.

In the reconnaissance of the forest covering the Coba ruins, a new sculptured monument was encountered, which may be designated as Stela 25. It is located approximately 1200 feet east of Structure XXV² in a shrine at the edge of a low mound. The base, which leans badly, stands to a height of 6 feet 7 inches; the upper part, broken into two large pieces and several fragments, measures 7 feet 10 inches in length, giving the entire stela a height of 14 feet 5 inches. Its width in the center is 4 feet 4.5 inches, which is narrowed to 4 feet just below the rounded top. From the middle, where it measures 13.5 inches in thickness, the monument tapers to the edges and top to a thickness of only 8.5 inches. Only the face is sculptured. The glyph-blocks, surrounding a large figure suggestive of those on Macanxoc stelæ, are badly eroded. An unsuccessful attempt was made to lift the leaning base, for the sculpture on its protected face does not appear as badly weatherworn. It is possible that a date could be obtained from this section.

Probably less than half of the ruins of Coba have been mapped. Group B extends to the north and northeast almost to Group D (Nohoch Mul), and eastward past Sacbe 8. This area, through which extends the new emergency airfield, should yield additional monuments. Two well-preserved temples on tall substructures have been revealed by the clearing at the east end of the airfield near Sacbe 8. Photographs of the temples, Stela 25, and the airfield clearing have been deposited in the files of the Division of Historical Research, Carnegie Institution of Washington.

COPAN—G. STRÓMSVIK³

The fourth season of cooperative work by the Government of Honduras and Carnegie Institution opened December 1, 1937. Mr. Strómsvik, in charge, was assisted by Aubrey S. Trik and J. M. Longyear, the latter de-

¹ C. L. Lundell, *The vegetation of Petén*. Carnegie Inst. Wash. Pub. No. 478, pp. 92-94 (1937).

² J. Eric Thompson, Harry E. D. Pollock, and Jean Charlot, *A preliminary study of the ruins of Coba, Quintana Roo, Mexico*, pl. 14. Carnegie Inst. Wash. Pub. No. 424 (1932).

³ For reports upon the investigations of 1935-1937 see Year Books Nos. 34-36.

voting himself to ceramic studies. Volunteer assistants were Miss Margaret Ennis, George E. Roosevelt, Jr., Donald Barrow, and Harvey Fite.

The work of protecting the main group of the ruins against further damage by the river is believed to have been brought to a successful conclusion during this season; the pole dam built in 1937 withstood the summer's floods, except for minor erosion around both ends during the peak of high water. As had been hoped, the diversion canal dug in 1936-1937 was amply widened and deepened by the river itself and when the floods subsided the stream confined itself to its new course. By repairing and extending the pole dam and by building it much higher with stone and earth removed from the ruins it was greatly strengthened.

Mr. Strömsvik continued excavation and repair of the ball court discovered in 1937. Like other Maya ball courts, it consists of a long rectangular playing area bounded on either side by a low vertically faced bench, from which sloping surfaces rise to a second vertical wall. The present court differs from other known examples in having been adorned with six monolithic parrot heads, three on either side (one at each end, and one at the center of the upper edge of the sloping surfaces). Although all six heads had been thrown down, the butt or tenon of the center head on the east side was found *in situ*, and the head at the south end of the west bench lay in such a position that its original location could be determined. These two heads were reset. They supply evidence which will permit eventual replacement of the remaining four.

On the east side of the court a narrow and much weathered hieroglyphic band runs upward from the center of the lower bench, crosses the sloping surface, and terminates at the central parrot head. From such glyphs as were legible Dr. Morley, in 1937, obtained a tentative reading of the date 9.17.4.0.0. In the course of this year's work it became necessary temporarily to remove one of the slabs of the band. It proved to be a re-used stone from a similar, earlier band, doubtless belonging to one of two older, dismantled ball courts found, in 1937, underlying the present court. The stone in question bore an excellently preserved and almost complete Initial Series introducing glyph whose variable element represents the Venus sign, which, according to Dr. Morley, should only occur at 9.4.0.0.0 13 Ahau 18 Yax, approximately 260 years prior to the apparent date of the latest ball court.

General repair of the ball court comprised re-laying the flat stones of the whole playing surface and parts of the sloping surface pavements, which had been forced out of level by pressure of tree roots; and rebuilding the vertical faces of the two basal benches.

Mr. Strömsvik also replaced certain elements of the Hieroglyphic Stairway and of its intricately carved balustrade, and made studies looking toward possible further reconstruction. To date have been added to what remained standing of the stairway **only** stones whose former position was known. Mr. Strömsvik, however, **considers** it advisable to complete the entire flight. Practically all the rest of the blocks are available, and although their exact original order will probably always remain uncertain, their resetting in the stairway would not only restore to this extraordinary construction its former impressiveness and beauty, but would preserve from

damage the stones at present lying scattered in the court. Needless to say, the elements so reset would be so marked as to distinguish them, for students, from those found *in situ* and those regarding whose place there is no doubt.

Mr. Trik devoted the season to Mound 11. This work was undertaken in order to preserve the remains of the temple and substructure, and to study the structure as an architectural unit in the complex of the Acropolis. The temple crowning the mound has undergone more or less excavation at various times since Maudslay's initial work there some fifty years ago. At the beginning of the 1938 season it was a tree-covered mound with little of the original construction showing through the vegetation and fallen débris.

The first consideration in the clearing of the mound was protection, from damage by material being removed from above, of the exposed sculpture of the "Reviewing Stand" at the foot of the south slope, and of Stela N and its altar at the base of the north side of the mound. The former was shielded by a covering of earth and stone and Stela N was guarded by erecting a barrier of poles halfway down the slope. Excavation was begun by opening a passage through the central chamber to the south doorway of the temple.

Clearing the center and west part of the interior of the temple revealed that on the north a gallery, about 30 m. long, extends the full length of the building. There is a small central chamber, 60 cm. above the level of the north gallery, and a small south vestibule on the same level as the north room. In the south wall of the north room, on either side of the central-chamber doorway, are two stair wells. The west well was completely excavated and reset to a height of eight risers. Although no part of the building exists above the spring line of the vault, it is certain that it formerly possessed a second story. This is indicated by the two stairways, by the massive solidity of the plan, and by the fact that the walls of the north room had been reinforced by two secondary walls about 1 m. thick, evidently built to help support the load imposed on the vault by upper construction too heavy for the original 3-m. span of the room.

In the floor of the central chamber an opening 1.0 m. by 60 cm. was found at the foot of the east wall. Débris and fallen wall stones had completely filled the opening, which proved to be the entrance to a shaft leading down into the substructure of the building. The shaft for 2 m. down is constructed with three step-like projections and a narrow ledge, which reduce its size to about 75 cm. by 40 cm. At the edge of the lowest projection it is enlarged to about 1.30 m. by 65 cm. and the walls run vertically down for 3 m. to a plaster floor. The masonry walls are built up from the level of the substructure and are an integral part of the temple construction. In the two side walls are pairs of post holes, probably used to facilitate descent.

Many human bones and teeth, as well as animal remains, were found mixed with the débris filling the shaft. At 25 cm. above the floor fragments of two large stone *incensario* lids were found, one decorated with a hieroglyphic band. Enough pieces were recovered to enable Mr. Thompson to read the date as 9.17.2.0.0 10 Ahau 8 Cumhu. Just below these fragments was a thin layer of earth mixed with ash and charcoal containing the remains of a scattered cache. Numerous obsidian blades, bird bones, human teeth, and sherds were found, as well as parts of a deer bone beautifully

carved in low relief with human figures and a hieroglyphic inscription. The remainder of the cache consisted of several small shell beads, bone tools, and a deposit of some vegetable fiber heavily coated with red pigment.

When the shaft was entirely cleared, a circular cut was found in the floor, the opening sealed with two rough stones. Below these were cached a small turtle carapace, two *Spondylus princeps* shells, and a rough, hard green stone.

The sculptural decoration within the temple comprises two hieroglyphic panels on the jambs of the north doorway, a highly conventionalized serpent mask framing the doorway to the central chamber, a similar mask around the opposite doorway of the same chamber, and two hieroglyphic jambs at the south doorway. A new inscription was uncovered at the west doorway of the north room. It had been concealed by the secondary construction and was badly scattered by the falling vault and walls. All the stones were recovered, however, and the inscription almost completely reassembled. The date was read by Mr. Thompson as 9.17.0.0.16 3 Cib 9 Pop. Although a great number of stones from the other panels were recovered, only a small part could be reassembled because certain necessary pieces have not yet come to light.

The walls and terraces of the substructure on the south side were cleared and solidified. This operation included repair of the "Reviewing Stand," built out from the lowest south terrace. The stand consists of a flight of six steps, 16.30 m. broad, leading to a battered terrace wall. The top step bears a hieroglyphic inscription flanked on either side by a kneeling figure holding a serpent in one hand and a scepter in the other. The steps were realigned, the inscription repaired, and the scattered parts of the figures reassembled. The heads and scepters of both figures had been lost until this season, when excavation uncovered those of the west figure. The head is a magnificent example of stone carving, well preserved and of an unusual facial type. The parts of the east figure had been lying in the West Court, badly weathered, but had not previously been recognized as belonging to the "Reviewing Stand."

An unusual feature of the substructure is a series of small rectangular niches, about 60 by 60 cm., built into the wall of the second terrace. Eight of these were excavated and repaired. Two were found to continue into the mound and to connect by a narrow passage. At either end of the passage is a small chamber about 1.30 m. by 60 cm. The whole construction was originally capped with large stones, some measuring as much as 1.70 by 0.50 by 0.35 m. No indication of the use of the chambers was found.

The west side of the mound was excavated in order to check terrace levels and construction details. A stairway with a battered balustrade was found to lead to the west doorway of the temple. No repair was carried out on this side. On the north side only enough was done to recover the plan of the temple and to reveal the condition of the façade. Very little of the north parts of the building remains.

Future work in the Mound 11 complex will be limited to solidifying the foundations of the temple on the north, now in very precarious condition, and to clearing the great stairway which descends on that side to the Court of the Hieroglyphic Stairway.

The Jaguar Stairway on the west side of the East Court was also repaired this season with the assistance of Mr. Harvey Fite of Bard College. This stairway, a secondary construction built over an earlier flight of steps, consists of a run of eight steps built out from a terrace wall which takes the form of a low bench about 1 m. high, a setback 60 cm. deep, and a battered wall 1.50 m. high, topped by a wide vertical course. In the battered zone on either side of the stairway a large rampant jaguar stands in high relief from the wall. Very little of the wall was found in position and the jaguars had completely fallen. Mr. Fite recovered all the parts and reassembled the figures in the wall, repairing the broken pieces with cement. The work was completed by resetting the terrace and realigning the stairway. A portion of the north end of the terrace was left open in order to show the original construction over which it was built.

Mr. Longyear this year inaugurated at Copan a series of ceramic studies which it is hoped may be extended to cover the southeastern part of the Maya area. The season's work was devoted to the pottery of Copan and included the digging of a number of test pits and trenches, as well as study of sherds and vessels recovered in past seasons while resetting stelæ and running trenches into the Acropolis. Through the courtesy of Dr. Jesus Maria Rodriguez, Minister of Public Education of Honduras, Mr. Longyear was able to bring a large sample of sherd material to the United States for study.

Advent of the rainy season unfortunately ended digging before excavation of the earliest deposits was completed, but on the basis of present material, three ceramic periods can be recognized. In the earliest or Pre-Acropolis period, Usulután ware, a type characteristic of the most ancient horizon so far identified in the highlands of Guatemala and in Salvador, was introduced into Copan. Although Usulután constitutes a large percentage of the Pre-Acropolis pottery, there is evidence that this ware did not make its appearance until the latest phase of the period. The succeeding Acropolis period saw the decline of Usulután and the beginning and rise of polychrome pottery. The zenith of Copan ceramics was reached at this time, both in variety of types and in excellence of decoration. Carved brown ware and hematite red ware are diagnostics for the latest phase of the Acropolis period. The last or Post-Acropolis period was represented by material from a dump lying on the surface of the Temple 22 pyramid. The sherds from this dump are unlike those found in the test pits and tunnels, being largely coarse-textured, thin-walled "utility ware," and, from their position above the latest floors of the temple, are believed to be the product of people who inhabited the Acropolis after the decline of Maya civilization at Copan.

Connections between the pottery of Copan and that of other sites in the Maya area are as yet indefinite. A few specimens of late Ulua Valley and Lake Yajoa pottery were recovered in deposits of the Acropolis period; and Peten polychrome types seem also to be represented here, but very meagerly. More work must be done in the areas surrounding Copan before the latter site can be assigned its proper place in the Maya ceramic complex.

The dating of Copan pottery periods remains vague, for tie-ins between stratigraphical test-pit material and dated monuments and buildings have not yet been satisfactorily determined. At present it might be suggested

that the Pre-Acropolis period goes back an indefinite length of time before the early part of the ninth cycle; that the Acropolis period runs from the early part of the ninth cycle to 9.18.0.0.0; and that the Post-Acropolis period follows that. The Acropolis period will almost certainly be subdivided after further digging and study.

Future work in this area should be concentrated on (a) a further study of Copan ceramics, embracing a search for both very early and very late types and the correlation of Copan types with dated monuments and buildings; (b) intensive research in Salvador on the problems of pottery sequences in that country and their relations with Copan and other areas; (c) investigations in Honduras to the east and north of Copan to determine the avenues and areas of contact between Copan and the Ulua drainage.

RECONNAISSANCE AND EXCAVATION IN BRITISH HONDURAS—J. E. THOMPSON

Early in 1938 Mr. Thompson made a reconnaissance of the northern part of the Great Southern Pine Ridge of Central British Honduras in an endeavor to find traces of a pre-agricultural horizon. This elevated broken area, the flora of which is pine, grass, scrub oak, and a type of palmetto, is quite unsuited to maize cultivation, yet it was known that a number of cairns, consisting of heaps of stones around slate shafts, were situated on many of the highest points. Excavation of these produced negative data as to when they were erected. No caches were found, but a few sherds including *incensario* fragments and a pressure-flaked flint point among the stones pointed to their use during the Maya period, presumably in the same way that mountain tops were used as shrines by the Chols and highland Maya into colonial times.

At the close of this reconnaissance a small outlying group at the ruins of Benque Viejo (Xunantunich) was excavated. Previous work at San José and Mountain Cow had revealed close similarities in the earlier ceramic phases, but rather marked divergence in the later phases, Mountain Cow late pottery resembling that of Uaxactun more closely than that of San José. Since the connections between late San José and late Uaxactun (Tepeu phase) pottery were largely indirect, and dependent on Mountain Cow, it was thought that study of late periods at a site about halfway between San José and Mountain Cow might clarify problems of contemporaneity. Benque Viejo was chosen as being very accessible and roughly equidistant from the three sites.

Excavation yielded three sequent phases, correlatable with San José III, Transition III-IV, and close of San José IV, and a fourth, unstratified, corresponding to Uaxactun 1a (Mamon). Since sherds from Benque Viejo of forms occurring in Uaxactun 1b (Chicanel) and Uaxactun II (Tzakol), which in turn correspond to San José I and II, are in the Peabody Museum, Harvard University, a complete series for this site now exists.

In the phase correlatable with close of San José IV, the resemblances to certain Tepeu features are more marked, and correspondences with Mountain Cow are close in all three phases. The last Benque Viejo phase shares with close of San José IV and San José V the absence or extreme rarity of polychrome pottery and introduction of carved pottery.

Excavation at Benque Viejo has, therefore, helped to clarify relations and divergences between San José, Mountain Cow, and Uaxactun, and confirms the disappearance of polychrome pottery toward the close of occupation already reported for San José.

At the close of the season Mr. Thompson proceeded overland from Benque Viejo to the northwest of the colony to visit a site reported by *chicleros*. This, named La Milpa from a nearby *chicleros'* camp, lies about 7 miles southwest of Warree camp close to the junction of the Victoria Creek with the Bravo River.

The numerous mounds, pyramidal and razor-backed (probably collapsed ranges of vaulted buildings), are in detached groups and are probably of early Peten masonry style since no dressed stone was observed during the two days spent at the ruins. Twelve stelæ had stood in front of various mounds on the east side of the main plaza. All were extremely weathered and most had fallen face upward. Apparently three were plain; the rest carved. Only one (Stela 7) was sufficiently preserved to yield a date. This proved to be 9.17.10.0.0 12 Ahau 8 Pax recorded by an Initial Series on the north side, the Calendar Round being repeated on the front. Altars stood before some stelæ. Two mounds, which seemingly formed a ball court of the sloped-wall type and with east-west axis, are situated on the east side of the plaza.

Mr. Thompson also visited Guatemala City to examine pottery from Uaxactun and Kaminal-juyu, and to discuss ceramic problems with the Chairman and Mr. R. E. Smith. He also proceeded to Copan, where he was able to recover two more dates. A stone *incensario*, part of which was found in the shaft of Temple 11, yielded (9.17.2.0.0) 5 Ahau 3 Cumhu reached from an earlier 9.16.13.0.0, and from a jamb of Temple 11 a Calendar Round date 3 Cib 7+ Pop, which is pretty surely 9.17.0.0.16 3 Cib 9 Pop, was recovered.

SAN ANDRES TUXTLA—KARL RUPPERT

At the invitation of Sr. Arq. Ignacio Marquina, Chief of the Office of Pre-historic Monuments of the Mexican Government, Mr. Ruppert as representative of Carnegie Institution spent the months of November and December 1937 in cooperative investigations with Sr. Lic. Juan Valenzuela and Sr. Agustín García Vega in the region of San Andres Tuxtla, southern Vera Cruz.

The greater portion of the time was spent at Matacapam and on the island of Agaltepec in Lake Catemaco. Sites near Matacanela and on the outskirts of Catemaco were examined. Matecapam comprises over forty mounds, of which three of the most promising were excavated in part and trenches for stratigraphic collections of potsherds were made in two mounds and three plazas.

One of the mounds excavated disclosed a pyramid rising in two terraces with batter and vertical super-element. The pyramid-facing of ground lava rock and adobe clay formed a hard durable surface which has well withstood the elements. A second mound, also rising in terraces, was definitely circular. The nature of its superstructure was not ascertained.

All material collected was sent to the National Museum in Mexico City, where Mr. Ruppert, on his return from the Institution's later expedition to Quintana Roo, spent the months of June and July with Sr. Valenzuela studying the ceramics. Distinctive local types for Los Tuxtlas were not determined. Pottery of the red-on-orange second period of Monte Alban and a gray ware with incised decoration similar to that of the third period of Monte Alban are relatively common throughout the various levels. Certain wares are reminiscent of the Isla de los Sacrificios, and the black painted faces of figurines common to the Huasteca also occur.

The southern Vera Cruz area is archæologically almost unknown. The above-noted preliminary investigations have yielded valuable information as to contacts with neighboring localities. However, the local wares must first be identified as a foundation for future work, as they will serve to correlate this culture with those already studied or under investigation.

CAMPECHE EXPEDITION—KARL RUPPERT

In continuance of the exploration of southeastern Campeche and southwestern Quintana Roo, undertaken by the Institution during 1932, 1933, and 1934, further work was done in this area in February, March, and April of the past season. This was made possible, in part, by generous financial aid provided by Mr. John H. Denison, Jr., who served as epigrapher on the expedition.

Mr. Denison and Mr. William E. Shepherd, the latter as cartographer, landed at Progreso, Yucatan, January 6, whence they proceeded to Merida. Here they were joined by Mr. Ruppert on January 8. Mr. J. C. Brydon of Merida kindly loaned the use of a storehouse for assembling and packing equipment and supplies. On February 1 the expedition left Merida by train for Hecelchekan, Campeche. The following day the journey was continued to the chicle camp of Nohsayah (N. $18^{\circ} 44.4'$; W. $89^{\circ} 14.6'$). This portion of the trip, made by airplane in an hour, would by pack mule have taken ten days. February 4 the party set out with pack mules for the *laguna* of Central Sabana, where camp was established from February 5 to February 8. From here trips were made to a number of small groups of ruins lying within a distance of from four to five hours' ride.

The first, Payan, to the east of the *laguna*, is a scattered group of mounds. The highest, which was probably the principal structure of the group, now shows only a few great stone blocks which served as facing. At some distance to the southwest are remains of a building which shows fourteen chambers. The west façade is pierced by three doorways and was decorated with stucco masks.

Desprecio, two hours' ride southeast from camp, is distinctive only in a U-shaped structure somewhat reminiscent of similarly shaped mounds seen at Rio Bec in 1933.

Buenos Aires, lying four hours' ride northeast of camp, was a group of low mounds and a partially standing six-chambered building. The structure carries a roof-comb of the single-wall type. Xaxbil, near the *aguada* of Garafon, is a small building with two rooms, and has façade decoration of large geometric scrolls and engaged columns at the corners.

On February 11 the expedition moved to Lagunita (N. $18^{\circ} 27.6'$; W. $89^{\circ} 18.9'$), where camp was maintained until February 18. The site of Okolhuitz, to the east of the *aguada*, is fairly large and arranged in two definite groups, each on the crest of a low ridge. Architecturally it is of Rio Bec type.

A day's trip was made to the site of Pasión del Cristo, where there are a great many large mounds and three fallen and one standing stelæ. No dates were obtained by Mr. Denison.

Three days were necessary to make the trip from Lagunita and examine the site of Corriental. In this group is one standing building with two towers. A passageway from a chamber behind one tower extends downward into the fill of the pyramid, through it to the other side, and then upward opening into a chamber behind the second tower.

From February 19 to February 25 the expedition camped at the *aguada* of Xpuhil (N. $18^{\circ} 30.6'$; W. $89^{\circ} 24.5'$). The ruins, lying twenty minutes' walk southwest of the *aguada*, consist of a few low mounds, except for one remarkable structure defining the west side of a large plaza. This building has twelve rooms and three towers, one placed at either end and one in the back center. The latter rises 20 m. above the podium on which the building rests. The towers have rounded corners and carry false stairways which were ornamented with great stucco masks.

On February 26 camp was moved to Aguada Carolina, and the following three days were spent in studying the ruins of Culucbalom, half an hour's ride to the east. The best-preserved structure defines the north side of a small court. The building contains six chambers and carries a roof-comb of the single-wall type. Of special interest is the south façade, ornamented with four engaged columns each decorated with two seated human figures in low-relief stucco.

While camped at Laguna Carolina Mr. Shepherd made observations for latitude and longitude, which are N. $18^{\circ} 34.1'$ and W. $89^{\circ} 27.7'$, respectively. The *aguada* at water level had a length of $\frac{3}{8}$ mile and a width of $\frac{1}{8}$ mile. On March 3, Mr. Denison made a trip to inspect some large mounds to the south. They proved to be Becan, the site surrounded by a moat, which was discovered by Carnegie Institution in 1934.

On March 7 the expedition left Aguada Carolina for Santa Rosario by way of So Aguada, Guitara, Carmalita, and Holaltun. A large group of mounds at Carmalita indicates a once well-planned, carefully laid out city. To the northwest of Holaltun recent *milpa* clearings have exposed a number of structures. The lure of treasure has led *chicleros* to dig in some of the chambers with consequent destruction of material.

The *aguada* of Santa Rosario was reached March 14 and there camp was maintained until the morning of March 22. The ruins known as Pechal lie half an hour's walk to the south of the *aguada* (N. $18^{\circ} 52.0'$; W. $89^{\circ} 29.8'$). The city was the largest encountered. Several of the buildings, each resting on a podium, show elaborate stucco-decorated façades. The east court proved of outstanding interest, as it was probably an amphitheater. The court measures 68 m. by 75 m. and is surrounded on all sides by a continuous mound broken only in four places, as if for entrances. An examination of the enclosing wall showed it to be lined on the inner side by a series of

eighteen to twenty steps. The seating capacity, very conservatively estimated, is placed at 8000. Four stelæ discovered at Pechal were sculptured with human figures, but carried no dates.

The last site visited was that of Peor es Nada (N. 18° 50.5'; W. 89° 22.2'), where the party stayed from March 22 to March 31. It is a rather extensive site with a number of buildings standing in part, which show ground plans of from six to fourteen rooms. Towers, as at Rio Bec, were seen on two structures, and there is a roof-comb of the single-wall type, 18 m. long, 5.35 m. high, and 1.90 m. wide. Peor es Nada is the only site where a ball court was found. From here the expedition returned to Noh-Sayab and then by airplane, on April 6, to Merida.

STUDY OF MAYA SCULPTURE—F. B. RICHARDSON

In attack upon the problems of any archæological area certain definite processes are indicated. First must come a preliminary stocktaking of remains, their general nature and their distribution. The second step should be the chronological ranking of those remains, in order to determine the extent and the location of population at different periods, and also to make clear the trends of cultural change. For this chronological ranking one should select types of evidence which most clearly reflect the passage of time.

In the Maya field the Initial Series dates supply the most obvious material for the establishment of sequences; and during the early years of Maya research they were relied upon almost exclusively. But while these inscriptions are of the greatest value as chronological landmarks, they cover a period of only about five hundred years. They supply, therefore, no evidence regarding the obviously long developmental stage which preceded the erection of the earliest monuments; and Initial Series ceased to be recorded several centuries before the coming of the Spaniards. Furthermore, monuments are few or lacking at many sites even of the epoch of greatest inscrip-tional activity; and none at all occur in the important peripheral districts.

For this reason it is necessary, in an attempt to deal with the whole area and the entire span of Maya history, to include intensive study of criteria other than epigraphic. Of these, pottery and the details of architecture are among the most useful and have been made the subject of special researches and surveys by the Division. Of almost, if not quite, equal importance is sculpture, an art in which the Maya were preeminent among the prehistoric peoples of America.

Maya buildings were lavishly decorated with carvings in stone and with figures modeled in stucco. The monuments bearing the above-mentioned hieroglyphic dates were also elaborately sculptured and, as Spinden demonstrated some years ago, it is possible by means of the dates on the stelæ to establish the trends of sculptural technique. Conversely, the nature of their carving permits determination, in many cases, of the age of stelæ whose inscriptions have become undecipherable through breakage or the erosion of time. The stylistic evidence offered by sculpture has therefore come to play a significant rôle in epigraphic as well as in architectural research. Furthermore, there are important linkages between sculpture, jade carving, and the

decoration of pottery. Finally, Maya art formed an integral part of the larger art field of Middle America. It influenced, and was influenced by, the work of other neighboring cultures.

The study of sculpture is thus of great importance; but the mass of sculptural and closely allied material is so great, and artistic and technical problems are so many, that epigraphers, ceramicists, and students of architecture must rely upon others for the highly specialized sculptural data they require. For this reason Mr. F. B. Richardson has undertaken a detailed survey of this aspect of Middle American culture.

The ultimate objective of Mr. Richardson's study is the comparison of Maya sculpture with similar developments in other parts of the world. Included among the immediate problems are: interrelation with adjoining cultures; identification of sculptural foci; tracing of trait diffusions within and without the Maya area; determination of the origin, the chronological development, and the influence upon the other arts of Maya sculpture. Such an investigation should contribute toward clarifying the history and society of the Maya.

The activities of Mr. Richardson, previous to the field season of 1938, were confined to the gathering of a comprehensive photographic file, and to examination of museum collections and the literature of the subject. During the winter of 1938, he made a rapid reconnaissance to the south and west of the Maya area, gathering data on regions which are archæologically little known. The season's work was devoted to four districts: western Salvador, the Pacific area of Nicaragua, southwestern Honduras, and the central Pacific coast of Guatemala and the adjacent highlands.

In western Salvador, Mr. Richardson examined El Limon, El Congo, Las Siete Princesas, Casa Blanca, Quinta Elena, and Tazumal, all in the department of Santa Ana. In addition, he visited collections in Chalchuapa and Santa Ana, notably those of Sr. Carlos Alvarez L. and Sr. Luis Fredrico Mathies. En route from Guatemala City to Santa Ana and thence to San Salvador, he stopped at Asuncion Mita, noticed mounds near Plata and Los Esclavos in Guatemala, and at San Andres in Salvador. In San Salvador he examined collections of the National Museum, of Dr. Oscar E. Salazar, Dr. Alfonso Quinones, and Mr. Schmidt.

In Nicaragua, Mr. Richardson visited Asososca, Nejapa, Nindiri, Diriamba, Masaya, Masatepe, and Granada. The major part of the work, however, consisted of studying specimens in the collections of the National Museum, the Presidential Palace, Sr. David Sequeira, Dr. Joaquin Gomez, Doña Josefa Vde. de Aquierre, Mr. F. Bunge, Mr. R. E. Frizell, Mr. R. E. Harding, Mr. F. Dreyfus, Mr. Maurice Marragou, Mr. Alfred Bequillard, Mr. Morelock, Sr. Jose Maria Gutierrez, Sr. Constantino Marengo, Mr. Arthur Vaughan, and the Jesuit College.

En route from Nicaragua to Gracias, southwestern Honduras, Mr. Richardson stopped in Tegucigalpa to study and photograph material in the Honduras National Museum. From Gracias he rode down the valley of the Rio Mejojote visiting the sites of Las Flores, Tapusuna, and Sehuateteque. He then continued on to the valley of the Rio Alash, reporting ruins at Cucuyagua and La Union, the latter being fairly extensive and having been called to

his attention by M. Rafael Girard through Dr. Jesus Maria Rodriguez, Minister of Public Education of Honduras. In this same valley near the towns of El Corpus, Corquin, Sensenti, and San Marcos, sites were reported to, but not investigated by him. With Santa Rosa as a base, two unsuccessful days were spent trying to locate ruins reported by E. G. Squier in 1854, lying roughly about sixteen kilometers to the north of Santa Rosa. A subsequent three weeks' stay at Copan enabled Mr. Richardson to benefit from the accumulated results of many years' work at that sculpturally richest of all ancient Maya cities. He also spent five days at Quirigua, whose stelæ are of outstanding artistic importance.

On the Pacific coast of Guatemala Mr. Richardson reconnoitered the lowland sites of Monte Alto and La Flora, El Baúl on the slope of the divide, and the highland sites of El Duranzo, El Naranjo, and Villanueva. From the lowland towns of Obero and Masagua, and the highland towns of Tecpan, Itzapa, El Tejar, and Antigua, sculptures not *in situ* were recorded. While in Guatemala City he studied collections at the National Museum.

The season's work necessitated frequent airplane travel allowing cursory geographical observation. In addition, reports gathered indicated unrecorded remains in areas surrounding those visited.

Such an extended itinerary opens up new vistas for future research and contributes toward a more adequate understanding of existing problems. The Pacific coast of Central America has long been recognized as a route of migration. Within this area in Guatemala, Salvador, Honduras, and Nicaragua, there appears to be a distinction between lowland and highland cultures. Certain traits are localized, while others cover a relatively large area. The "Chorotegan" sculpture of Nicaragua was found to have no close relationship to that of other known areas. Evidence gathered tends to weaken the hypothesis that the Chorotegan culture antedated that of the Maya. Certain sculptures from southern Vera Cruz, Tabasco, and northern Chiapas are believed to have affiliations with those of the Pacific coast of Guatemala. The Rio Lempa in eastern Salvador apparently is close to the fusion point of northern and southern traits. In the department of Chontals, Nicaragua, remains differ from those of the lake region.

In Honduras, the archæologically fertile and hitherto unexplored Alash River valley produced, among other sites, one with definite Maya traits in conjunction with surface material of non-Maya character.

Geographically and in part culturally the Guatemala highlands have much in common with western Salvador. The headwaters of the Rio Alash interlock with those of the Rio Lempa and together with the Rio Mejocote they join to form the Rio Jicatuyo. With the exception of the Comayagua Valley drainage, the Rio Jicatuyo is the largest tributary of the Ulua River. It would therefore seem that further investigations in the western half of Salvador and in the Alash Valley should contribute toward a more adequate understanding of the Guatemala highlands and of the similarity between ceramic material from Salvador and that of northwestern Honduras. Under the Institution's present program Nicaragua lies too far afield for immediate additional attention. Further work on the Pacific coast of Guatemala should help to determine the geographical limits, chronological sequence, and routes

of migration of certain Middle American cultures. That area, accordingly, would seem most important for intensive study.

MINOR ARCHÆOLOGICAL STUDIES IN GUATEMALA—R. E. SMITH

Small clay figurines, for the most part in the form of human effigies, are among the most characteristic and, archæologically, the most significant remains of the so-called "Archaic" culture of Middle America. They were also produced in large quantities by the Maya, the Toltec, the Aztec, and other people of later times.

Mr. Smith, in his work upon the pottery of Uaxactun, has been giving special attention to the figurines from that site. The earliest figurines of Uaxactun have proved to be similar to specimens from apparently very old cultures in the Guatemala highlands; and these, in turn, seem allied to the Archaic figurines of Mexico. Mr. Smith has accordingly been led to the making of a comparative study of all such material, that from Mexico as illustrated in the many publications of Vaillant; that from the Guatemala highlands comprising the collection made by Dr. Ricketson and the Chairman in 1935 at Finca Miraflores, and by the Chairman in 1936 and 1937 at La Esperanza, both localities which form part of the great archæological site of Kaminaljuyu.

The Kaminaljuyu figurines were found by Mr. Smith to include several distinct types. But the specimens from La Esperanza having come from disturbed deposits, and those from Miraflores from a very small excavation, provided no information as to whether the observed types were contemporaneous variants or whether they represented a stylistic sequence.

In order to gather further data Mr. Smith excavated a new and larger section at the Finca Miraflores, isolating a square column of earth, recording its layers, and collecting all material in stratigraphic order. Great numbers of potsherds were recovered, which add significantly to our knowledge of the early ceramics of the region. The figurines, of which over fifty came to light, are at present being studied by Mr. Smith.

Mr. Smith also made a trip, during the spring, to Tiquisate on the Pacific coast plain of Guatemala, where the extensive operations of the United Fruit Company have led to discovery of many archæological remains. These have been noted, and arrangements have been made with the Company officers at Tiquisate for notification of the Institution's office in Guatemala City of further finds.

CERAMIC TECHNOLOGY—ANNA O. SHEPARD

The plan of the Ceramic Technology Project has been to conduct concurrently studies of both Maya and Anasazi (Basket Maker-Pueblo) pottery. This division of effort is advisable because the archæological investigations of the Division are being conducted both in the Maya field and in southwestern United States, and also because a greater diversity of materials and problems is thus presented. The methods of pottery making in the two areas are in many ways distinct and the course of ceramic development differed. A broader knowledge of primitive techniques is therefore gained, and, at the same time, opportunity is afforded to work out the evidence of

culture contacts and influences as shown by trade in pottery and spread of specialized techniques of pottery making at two levels of cultural development. The purpose of the technological laboratory is to make extensive and systematic investigations which may be expected to yield data of general historical interest, rather than to provide facilities for analyses to be used for miscellaneous and unrelated identifications. Cooperative studies with other institutions are therefore made only when material contributes to the solution of the broad problems outlined for investigation.

Research in the Maya field during the year centered mainly around the completion of technological notes on the pottery of San José, British Honduras, for Mr. Thompson's report on this site. The various pastes had in the main been identified the previous year, but more detailed studies and comparisons with pottery from Uaxactun showed definite possibilities of tracing to their source a portion of the limestone-tempered pastes which are so widely distributed in the lowland region. The tuff-tempered wares regarded as intrusive in San José were reexamined for comparison of properties of the tuff with that in pottery from Copan, San Agustín Acasaguastlan, Kaminal-juyu, and Zacualpa. The study of San José pastes was supplemented by the microscopic examination of sherds from Holmul, Tayasal, and Baking Pot in the Peabody Museum at Harvard. As the paste of over 1400 sherds was identified, our knowledge of the distribution of tuff-tempered wares in the lowland region, a phenomenon of primary interest because of the questions of trade which it raises, was extended; and the necessity of considering frequency of occurrence in relation to natural resources was demonstrated. The marked differences in the proportion of tuff temper, both by period and by ware, in the various sites shows that distribution and relations are complex. Extensive studies will accordingly be necessary in order to determine the full significance of the numerous occurrences of tuff-tempered pottery in the limestone area.

Maya potters gave especial attention to vessel finish; and brightly colored, highly lustrous surfaces are characteristic of the monochrome slipped wares of the Peten. The properties of these slips indicate the use of specialized techniques which should provide important clues for study of the spread of traits. A number of different experiments were made to determine whether or not these surfaces were coated with some organic material after firing and the effect of such material, if present, on luster and color. Some positive evidence was obtained and a number of problems outlined for future investigation.

Work in the Anasazi area centered around the study of material from Mr. Morris' excavations in the Four Corners region and the initiation of a more extensive study of Rio Grande glaze-decorated ware. The petrographic examination of La Plata pottery had shown a few intrusive sherds containing a distinctive igneous rock—a poikilitic sanidine basalt. This rock was identified with that which occurs abundantly in corrugated pottery from Chaco Canyon. In order to gain some notion of frequency of occurrence in Chaco pottery, over 2000 sherds from stratigraphic tests made by the Pueblo Bonito expedition were examined through the courtesy of Mr. Neil M. Judd. Although its proportion is high, no source of this rock is

known in the Chaco, and in October a field trip was made to examine igneous rocks in the Navajo country east of the Chuska Mountains and to collect sherds from ruins in that district. The occurrence of the above-mentioned basalt in the Chuska Mountains and its consistent use for temper in sites of the Chuska region raised the question whether or not the ancient Chuskans were specialists in the manufacture of corrugated ware, from whom pueblos to the east and north obtained a portion of their corrugated vessels. On the same field trip, the Red Rock country was visited in connection with studies of Mr. Morris' Basket Maker III pottery from this area. Here problems center around the absence of coarse quartz sand and buff-burning clay which characterize the bulk of the early Red Rock ware. Examination of entire vessels in the Red Rock collection and a study of sherds shows the presence of igneous rock temper, some of which is certainly intrusive.

Rio Grande glaze-decorated pottery offers an exceptional opportunity to investigate the development and spread of a specialized technique, since the area is well defined. Geologic formations within it are diverse with consequent wide variations in pottery materials, and changes in style are sufficiently definite to form time markers. The possibility of recognizing through which villages glaze ware was introduced and how rapidly its manufacture spread was brought out in the Pecos investigation and was again demonstrated this year when a report was made on pottery from Unshagi in the Jemez Canyon for Mr. Paul Reiter of the State Museum of New Mexico. It was therefore decided to make a general survey of Rio Grande glaze ware, the work being initiated and outlined by the examination of sherd collections in the Laboratory of Anthropology at Santa Fe, made available by courtesy of Mr. Kenneth M. Chapman.

The principal advance made in the Ceramic Technology Project during the year was in extending the scope of the work to include chemical analysis. Simple qualitative tests and a few quantitative determinations had previously been carried out, but adequate facilities for chemical analysis were not available until the project was moved to Boulder in October. A laboratory was then equipped and the essential apparatus for micro-qualitative and micro-quantitative analyses obtained. Basic training in analytical chemistry and micro technique was taken by Miss Shepard during the year while devoting full time to her regular duties.

MAIZE INVESTIGATION—R. STADELMAN

In previous reports there has been made clear the outstanding economic importance of maize throughout Maya history. There has also been stressed the significance, for studies of the rise and diffusion of native New World culture, of determining the place of this cereal's origin. The latter problem has been under attack for several years by Mr. J. H. Kempton of the United States Bureau of Plant Industry in cooperation with Carnegie Institution. During the past year Mr. Kempton, using material gathered on former field expeditions, has been engaged in laboratory investigations of the genetics of *teosinte*, a plant suspected to have been involved in the ancestry of maize.

Mr. Kempton has also directed the study which Mr. Raymond Stadelman has been making of maize agronomy in the highlands of Guatemala.

Mr. Stadelman took up residence in January 1937 at the Indian village of Todos Santos in the department of Huehuetenango, Guatemala, as reported in the last Year Book. He has now observed and recorded in detail the agricultural practices of a typical Indian community throughout a full agricultural year. This has enabled him to prepare a list of definite questions regarding the agronomic and economic aspects of maize culture which he is at present using for an extended survey of other towns in the highlands. The intensive and extensive information being obtained by Mr. Stadelman will provide, for the first time, accurate data upon farming in the mountainous parts of Guatemala, which will be of great value for comparison with similar data already collected by Messrs. Kempton, Emerson, and Steggerda in the lowlands of northern Yucatan.

ETHNOLOGICAL, SOCIOLOGICAL, AND LINGUISTIC RESEARCH—R. REDFIELD,
M. J. ANDRADE, S. TAX, A. T. HANSEN, A. VILLA R.

As indicated in the preceding Year Book (p. 145), Mr. Villa's expedition to Quintana Roo in the winter of 1936-1937 completed the field work for the study of village and city life in the peninsula of Yucatan. Mr. Villa spent part of the year 1937-1938 in preparation of his report on the east central Quintana Roo villages; it is expected that this will be ready for publication by January 1, 1939. Dr. Hansen devoted part time to further work on his monograph on Merida; this should be ready in 1939. In the summer of 1937 Dr. Redfield began the preparation of the summary and comparative volume on culture and civilization in Yucatan.

The comparative study of highland societies of Maya peoples was prosecuted during the year here reported by Dr. Tax and by Mr. Villa. Dr. Tax's year was chiefly devoted to preparing for publication material collected during the two previous seasons in Panajachel, Guatemala. After returning from the field in June 1937, field notes and data contained in such forms as genealogies, schedules, and maps were organized. At the same time a draft of one chapter of the report was written to see if the purely "cultural" data—the knowledge, beliefs, technology, science, values, and modes of behavior—could not be best presented from the native point of view almost as if an Indian himself were writing it. Since the method appeared fruitful, it is being continued.

During the last six months of 1937 Sr. Juan Rosales, an Indian of Panajachel trained in field methods by Dr. Tax and Dr. Andrade, remained in Panajachel to collect additional data and to resolve questions put by Dr. Tax. This necessitated considerable correspondence. At the same time, Mrs. Tax devoted herself to notes transmitted by Rosales.

At the end of December, Dr. Tax left again for Guatemala, taking up residence in Panajachel. During the three months that followed, he accomplished three missions: first, he filled in and completed his studies of Panajachel culture, clearing up doubtful points for his report; second, he installed Sr. Rosales in the town of San Pedro la Laguna, there to do an ethnological study under his direction, and conferred with him a half-dozen times both

in San Pedro and in Panajachel; and third, he made practical arrangements for his and for Dr. Redfield's next field seasons. In the course of this work, much was learned about house building and about the relations of Indian and *ladino* laborers and artisans in Agua Escondida; and as a house in Chichicastenango was taken only after many vain attempts to obtain land or a house owned by Indians, considerable new insight into Chichicastenango attitudes and modes of living was attained.

At the beginning of April Dr. Tax returned to resume work on his Panajachel report, now devoting himself to writing. By the end of June something more than two hundred pages of typescript were ready and almost as many more in various stages of preparation. Plans call for the virtual completion of the report by the beginning of October, when Dr. and Mrs. Tax will resume work in Guatemala, returning to Chichicastenango to complete the study begun there in 1934-1935.

By this time the sociological and ethnological problems to which attention is being directed are more clearly delineated, and the work should go on more rapidly. By the end of another year intensive studies of three communities (Panajachel, Chichicastenango, and San Pedro la Laguna), representing the three linguistic divisions of the midwestern highlands, will probably have been completed; it will then be possible to undertake comparisons of a more intimate nature than those afforded by the reconnaissance and surveys of the past.

The work done in connection with this project, as well as that done by others, notably La Farge and Schultze-Jena, has indicated many common resemblances as well as certain important differences among the Maya of the highlands of Guatemala, and the facts available have further suggested that the peoples of eastern Chiapas form a part of the same general type and region. Accordingly it is desirable to extend the guided sampling of Maya ethnology to Chiapas. Notes on the Tzeltal, Tzotzil, and Chol have been provided by Pineda, Starr, Blom and La Farge, Becerra, and others; but the information provided in their notes is inadequate to enable us to determine the significant problems in this area. Accordingly Mr. Villa spent two months early in 1938 making a reconnaissance of Tzeltal settlements. San Cristobal de Las Casas served naturally as a base. Fifteen communities, from Amatenango on the south to Petalcingo on the north, were visited; these included both highland and lowland settlements. From a few hours to several days were spent in each community. Mr. Villa strove to secure his ethnographical information from the Indians, rather than from the *ladinos*, and to investigate matters such as type of settlement, Indian-*ladino* relationships, and form of government, as are summarized for the communities of the midwestern highlands of Guatemala in a recent paper by Dr. Tax (*American Anthropologist*, vol. 39, pp. 423-444, 1937).

It is expected that the material secured by Mr. Villa will be published in a short article, but some of the suggestive findings may be mentioned here. Brief mention of Indian surnames among the Tzeltal is made by Starr; nothing is said on the subject by Blom and La Farge. Villa has established the fact that the highland Tzeltal have exogamous surname groups; the names are descriptive, or refer to animals or plants. Furthermore, certain of the

highland villages are divided into antagonistic subcommunities (*calpules*), one with lands to the north, the other with lands to the south. In Oxchuc a principal annual ceremony attends the transfer from one *calpul* to another of a certain sacred book. This book, a manuscript containing apparently orders set down by Spanish authorities in the seventeenth century, is kept in a special sacred structure. Villa obtained further information on the nineteen-month calendar; it is apparent that it is still used in connection with the agricultural round.

It is expected that this reconnaissance will be followed by a more intensive study, to be carried on by Mr. Villa, of one of these Tzeltal communities.

Dr. Andrade continued the preparation of his linguistic manuscript of Yucatec; it is expected that it will be ready for publication in the spring of 1939.

PUBLICATIONS, SECTION OF ABORIGINAL AMERICAN HISTORY—
MARGARET W. HARRISON

In June 1938 a collection of twenty-four taxonomic papers was published under the title *Fauna of the caves of Yucatan*. In these papers A. S. Pearse of Duke University and his collaborators include data on many hitherto unreported species. This publication forms a companion volume to *The cenotes of Yucatan, a zoological and hydrographic survey*, which appeared in 1936.

A medical survey of the Republic of Guatemala by George Cheever Shattuck of the Harvard School of Public Health, and four collaborators, will be published in August 1938. The material is based upon medical observations made in Guatemala by Dr. Shattuck and Dr. Curth, and upon information on the distribution and prevalence of diseases in the republic, as shown by data collected from various public and private sources. Medical problems of special interest are discussed in detail, and outstanding public-health questions are considered briefly. The text is fully substantiated by statistical tables.

In *Modern Maya houses: a study of their archæological significance*, Robert Wauchope describes modern Maya architecture in detail, both as an ethnographic record and to facilitate interpretation of prehistoric house remains. He devotes particular attention to abandoned houses and to the remaining traces of their superstructures. Verbal, documentary, linguistic, functional, and archæological evidences of the age and geographical distribution of constructional features are considered, and several ethnological problems are proposed. The volume, extensively illustrated, will be published in August 1938.

Progress has been steadily made on the proof of *The inscriptions of Petén* by Sylvanus G. Morley. One volume of plates was published in 1937 and it is expected that the four volumes of text will appear before the end of 1938.

The Titles of Ebtun by Ralph L. Royce is now in press. This book is a study of the archives of Ebtun, an Indian town in eastern Yucatan (1600–1833). The documents, in Maya and Spanish, comprise agreements with

other towns, transfers of property, and records of lawsuits, furnishing a historical link between the sixteenth-century inhabitants of this region and the present population. Following a historical introduction, the documents are transcribed, translated, and annotated.

The manuscript of *Excavations at San José, British Honduras* by J. Eric Thompson is also in press. Whereas most excavations in the Maya area have been confined to the impressive ceremonial centers, the culture here described is that of a small town, which may be considered more typical of the general culture level. The architecture, pottery, artifacts, and caches of San José are discussed. The section on ceramics, fully illustrated, is amplified by the inclusion of Anna O. Shepard's study on the pastes and slips of San José pottery.

The manuscript of a small paper entitled *The age and provenance of the Leyden Plate* has been completed by Frances R. and Sylvanus G. Morley. This paper will form one of the *Contributions to American Archæology* and will probably go to press before the end of 1938.

Earl H. Morris has finished the manuscript of a large report, *Contributions to the archæology of the La Plata district: southwestern Colorado and northwestern New Mexico*. An appendix on the technology of La Plata pottery has been written by Anna O. Shepard.

SECTION OF POST-COLUMBIAN AMERICAN HISTORY

HISTORY OF THE UNITED STATES

The fourth volume of Leo F. Stock's *Proceedings and debates of the British Parliaments respecting North America* was published in November 1937. Dr. Stock will spend the summer of 1938 in England, gathering materials for the final volumes in this series. In August he will represent the Institution at the Eighth International Congress of Historical Sciences at Zürich.

The third and final volume of *Historical documents relating to New Mexico, Nueva Vizcaya, and approaches thereto, to 1773* was published in January 1938. These documents were collected by Adolph F. A. and Fanny R. Bandelier, and edited by Charles W. Hackett of the University of Texas. The first two volumes include the Spanish texts accompanied by English translations; the third volume contains translations only.

Under a post-retirement grant, Edmund C. Burnett has been engaged in preparing a volume interpretative of the Continental Congress, 1774-1789, and based primarily on the eight volumes of his *Letters of members of the Continental Congress*. A large part of the book is written and most of it has been revised.

The annual *List of doctoral dissertations in history now in progress at American universities* was compiled by Margaret W. Harrison, editor of the Division. The issue of December 1937 contained 1040 titles of theses upon which candidates for the doctorate in history were engaged. This pamphlet is published by the Division of Historical Research and is distributed to

libraries, educational institutions, members of university faculties, and periodicals in the field of history.

David M. Matteson, indexer of publications emanating from the Section of Post-Columbian American History, prepared the indexes to the above-mentioned volumes by Dr. Stock and Dr. Hackett.

During 1937 and 1938 work on the *Guide to the materials for American history in the libraries and archives of Paris* was continued by John J. Meng under the supervision of Waldo G. Leland. The manuscript notes prepared by Dr. Leland and M. Abel Doysié in years past are being analyzed, coordinated, and in some cases amplified, in preparation for definitive publication. Thus far, attention has been confined to the French Foreign Office archives, which are extensive enough to require a separate volume of the *Guide* devoted solely to their analysis. Approximately three-quarters of the material for this depository has been gone over and analyzed in a first draft that will need little, if any, revision before submission to the printer. The material covered thus far includes all the "correspondance politique" with the exception of a few volumes in the "fonds Espagne," which latter volumes will be disposed of within the next two months. There remains the much smaller group of materials for the "mémoires et documents" section of the archives. It is hoped that all remaining work on the Foreign Office archives will be completed before the end of the present calendar year. It should therefore be possible to publish an additional volume of the *Guide*, devoted to the Foreign Office, during the course of 1939.

It should be noted in addition that a few important lacunæ in the notes already at hand are being disposed of by M. Doysié, working in Paris under a special grant. With these lacunæ taken care of, the resulting analysis of the Foreign Office archives should be reasonably complete from the earliest years to 1840, in some cases even as late as 1870.

HISTORY OF YUCATAN

During the past year Sr. J. Ignacio Rubio Mañé has continued his search for materials on the colonial history of Yucatan in the Archivo General de la Nación in Mexico City. The volume-by-volume survey of the *Ramo de civil*, which had progressed as far as volume 1250 by July 1, 1937, was carried through to volume 2302, the last in the series. The uncatalogued part of the *Ramo de tierras*, volumes 2972 to 3623, has also been searched. In these two *ramos* a mass of new material for the history of Yucatan, especially for the eighteenth century, has been found. The documents deal with governmental organization and administrative policy, ecclesiastical affairs, Indian administration, *encomiendas*, the economic history of the province, suits over lands, and private business transactions. A series of *expedientes* relating to the abolition of the *encomienda* system in 1785-1786 deserves special notice. Photographic reproductions of several important items have already been made and others will be reproduced during the year 1938-1939. After completing his work on the above-mentioned series, Sr. Rubio Mañé started a survey of a number of less extensive series, such as *Arzobispos y obispos*,

Real audiencia, *Expolios*, *Real acuerdo*, etc. He will be engaged in this work during the greater part of the coming year.

Dr. Robert S. Chamberlain spent two months (July 17—September 24, 1937) in Mexico City, after completing his investigations in the archives of Guatemala, El Salvador, and Honduras. During this time he examined several sections of the Archivo General de la Nación, especially the papers of the Hospital de Jesus, as well as parts of the Archivo de Notarios, the Archivo del Ayuntamiento, and the Cathedral archive. Unfortunately, very few documents pertinent to his investigations on the history of the conquest of the Maya area were found.

Since his return to the United States in October 1937, Dr. Chamberlain has been engaged in the preparation of certain materials for publication. A résumé of the history of the conquest of Yucatan, based on the more extensive and detailed sections of his projected history of the conquest of the Maya area, has been largely completed. This will be incorporated in the introductory section of the work on the life and times of Fray Diego de Landa being prepared by Mr. Scholes. Dr. Chamberlain has also written a preliminary draft of a chapter on the exploration and conquest of the Acolan-Tixchel area which will form part of the larger work on the *cacicazgo* of Acolan-Tixchel on which Mr. Roys and Mr. Scholes are also collaborating. During the last three months of the year 1937–1938, Dr. Chamberlain devoted most of his time to the preparation of a short monograph on the Castilian origin of the *encomienda* system, which should be ready for publication by the autumn of 1938.

Mr. France V. Scholes and Miss Eleanor B. Adams gave most of their time during the past year to the preparation of two volumes on the administration of Don Diego Quijada, who served as *alcalde mayor* of Yucatan from 1561 to 1565. It was hoped that the manuscript of this work would be finished before the end of 1937, but the decision to add a considerable number of documents to the series as originally planned made it necessary to carry the work over into 1938. These volumes, which are now in press, will contain eighty-five documents and a lengthy introduction. The latter will describe the development of Yucatan from 1550 to 1561, the beginnings of the Quijada régime, the famous investigation of Indian idolatry made by Quijada and Fray Diego de Landa in 1562, the increasing resentment inspired by Quijada's government, especially his attempt to abolish burden bearing, the *residencia* of the *alcalde mayor*, and the final vindication of Landa for his share in the unhappy events of 1562. As stated in the Year Book for 1937, the material published in these volumes will provide the documentary basis of part of the work on the life and times of Landa being prepared by Mr. Scholes with the collaboration of Dr. Chamberlain, Miss Adams, and Sr. Rubio Mañé.

Mr. Scholes spent part of November and December 1937 in Mexico City in conference with Sr. Rubio Mañé and in negotiations with the editor and publisher of the *Biblioteca histórica mexicana* series, in which the two volumes on Quijada are to appear. Late in June 1938, Miss Adams left for Mexico City, where she will spend several months carrying on investigations in the Archivo General de la Nación in collaboration with Sr. Rubio Mañé.

During the past year volumes II and III of the *Documentos para la historia de Yucatan*, edited by Mr. Scholes, Sr. Carlos R. Menéndez, Sr. Rubio Mañé, and Miss Adams were published. Volume II contains a series of forty-four documents illustrating ecclesiastical organization and the development of the missions from 1560 to 1610. Volume III contains a report on general conditions in Yucatan in 1766 entitled *Discurso sobre la constitución de las Provincias de Yucatan y Campeche*. Included in the volume are two appendices, the first describing the government of Campeche in 1746, the second being a census of Yucatan for 1790. In the *Handbook of Latin American studies*, 1936, pp. 387-432, Dr. Chamberlain published "A report on colonial materials in the government archives of Guatemala City."

Mr. R. L. Roys devoted the first part of the period under review to revision and completion of maps of the prehistoric Yucatecan Maya states, or so-called provinces, of the Cupuls, Sotuta, and Mani, from topographical material gathered during the spring of 1937 and described in a previous report.¹ The first two will appear in *The Titles of Ebtun*,² and the last will accompany the publications of the Xiu *probanzas* and related documents.

The two series of documents mentioned above constitute a general history, from the native point of view, from the Spanish Conquest down to the period covered by the ethnological studies of the modern Maya. These papers deal principally with the more material facts of existence and may be supplemented in course of time by a study of native intellectual and religious life during the colonial period. Some of the material for this will be found in the mixture of Spanish astrology and Maya science, both of which were closely bound up with religious ideas, recorded in the Maya language in the later Books of Chilam Balam.

At the present time, however, it has seemed desirable to inquire more closely into what the white man found when he arrived in the various parts of the Maya area: the state of affairs at the time of this contact, as distinguished from subsequent developments influenced by European culture, on one hand, and previous conditions no longer existing but disclosed by archaeological investigation, on the other.

There are some indications that more or less similar conditions may well have existed for at least three centuries prior to the Conquest in the highlands of Guatemala and perhaps considerably longer in regions between that area and Yucatan. In Yucatan, however, there was a great political and social revolution about the middle of the fifteenth century. Its more conspicuous effects were the breaking up of a centralized government and the abandonment of the stone-vaulted buildings, which were replaced by more or less perishable structures with thatched roofs. In the Old World such a decline in architecture has been either more gradual or the result of invasion and immigration by less cultured peoples, which was not the case in Yucatan at this time. Much of the previous state of affairs, which reminds us in some respects of the conditions in the highlands of Guatemala at the time of the Conquest, was still a matter of general knowledge when the Spaniards con-

¹ Year Book No. 36, p. 23.

² Carnegie Inst. Wash. Pub. No. 505.

quered Yucatan, so it may be possible to trace the causes and effects of this famous crisis in aboriginal American history.

New documents discovered by Mr. Scholes in the archives of Mexico and Spain have not only added to the sum of our knowledge, but also required a fresh examination and reinterpretation by Mr. Roys of historical sources which have long been known.

For the *Report and census of the Indians of Cozumel, 1570*, already mentioned in a previous report¹, the introduction has been enlarged and re-written from the study of a considerable number of related documents furnished by Mr. Scholes.

An ethnological study has also been made by Mr. Roys of the proceedings of Landa's inquisition in 1562, which furnishes a very appreciable amount of new material. In Mr. Roys' opinion, the human sacrifices and other pagan ceremonies performed in Christian churches during the second decade after the Conquest suggest that temple ritual had continued to retain much of its importance, in spite of the decline of temple architecture and the prominent part played by the private oratory.

Sacrifices were made to bring rain and favorable weather for the crops, to avoid recurrence of hurricanes, and for the benefit of ailing chiefs. It is of especial interest to learn that the *cenote* cult was not confined to Chichen Itza. While some victims were still taken to that site, in numerous cases the bodies were cast into local *cenotes* in the Sotuta district. Although Christian influences are already seen in the crucifixion of some victims, a logical development since the cross was a Maya religious symbol, the details of other forms of sacrifice are invaluable to the ethnologist.

We are introduced here to a new category of Maya deities, the gods of the different lineages or name groups. The greatest of these, Zacalpuc, we already know as one of the early Mexican invaders of Yucatan and the head of a lineage. Indeed, he still figures in the prayers of the modern native herb doctors.

Now that photographs of the oldest copies of the Pech documents have been acquired, Mr. Roys has undertaken a new transcription and annotated translation of these papers. They consist of two collections, one from the town of Chicxulub and the other from Yaxkukul. These towns formed the subject of a topographical study² in 1937. Brinton published the text and translation of the most important Chicxulub document in 1882, and Martínez did the same for all the Yaxkukul papers in 1926, but did not include the official Spanish translation made in 1769.

These important documents are probably the earliest Maya narratives written in European script that have come down to us and include accounts of the Spanish Conquest by two native chiefs who were allies of the Spaniards. In consideration of Dr. Chamberlain's current study of the conquest of Yucatan and a number of later documents from the Pech area discovered by Mr. Scholes in the Archives at Seville, the publication of the entire series of the Chicxulub and Yaxkukul papers with new annotations seems desirable at this time.

¹ Year Book No. 33, p. 107.

² Year Book No. 36, p. 23.

SECTION OF THE HISTORY OF SCIENCE ¹

Introduction to the History of Science. Notable progress has been made by Dr. George Sarton in the preparation of volume III, dealing with the fourteenth century, 152 articles, some of them of considerable length, having been written. Though the redaction of these articles is now meant to be final, it is likely—judging from earlier experience—that before the work is completed, many will require additions and revisions, and that a few may have to be entirely rewritten. All these notes concern the authors of scientific texts in Latin or in the vernaculars of western Europe.

The end of the Latin and western European part (by far the largest of the book) is now in sight, and it is hoped that the analytic stage of the whole work may be completed within the next academic year. This very elaborate and patient analysis is merely a preparation for the synthesis of fourteenth-century science and learning which will then be undertaken.

Dr. Welborn has continued to assist Dr. Sarton, checking data and adding items to the bibliographies. Dr. Pogo has also assisted Dr. Sarton and has continued his astronomical studies bearing on the problem of the correlation of Maya and Christian chronologies. His report follows:

Maya astronomy. It becomes increasingly difficult, because of their highly technical subject matter, to make the annual summaries of this research concise, yet intelligible both to Mayologists and to astronomers. No technical explanations will be given in the present report. Work on the various aspects of the correlation problem proceeded slowly, the two principal investigations being centered on the lunar and the planetary records of the Maya. A considerable amount of time was devoted to the reading of the proofs of Dr. Morley's forthcoming *Inscriptions of Petén*; all the Maya dates and calendrical computations found in the work were checked. The appended bibliography indicates the progress of the theoretical investigations dealing with eclipses in general, and of the accumulation of observational data on the visibility of penumbral lunar eclipses in particular; these studies, necessary for a deeper insight into the structure of the Maya records preserved in the Dresden Codex, have yielded results which should be of interest to students of Mesopotamian-Mediterranean eclipse records.

Scientific incunabula. The publication of Arnold C. Klebs' *Incunabula scientifica et medica* (*Osiris*, vol. 4, pp. 1-360, 1937), a work which had been in preparation for a great many years, made it possible to undertake a study which Dr. Sarton has had in mind for a long time but which he had deliberately postponed until Klebs' preliminary survey became available. As Dr. Sarton has frequently stated, it does not suffice to record when, where, and how a discovery has been made or a scientific treatise written; it is equally necessary to set forth the tradition of that discovery or of that treatise, for if the discovery or the treatise had not been transmitted it is almost the same as if the former had never been made, or as if the latter had never been composed. In the history of scientific tradition it is always important to determine exactly when it first occurred in print, for in most

¹ Twentieth annual report for the period from July 1, 1937 to June 30, 1938 (previous reports appeared in Year Books Nos. 18-36, 1919-1938; the twelfth and following also appeared in *Isis*, the latest in vol. 28, pp. 87-91, 1938).

cases the printing of a text meant its final salvation for posterity. Thus in volumes I and II of the *Introduction* Dr. Sarton has taken pains to indicate the earliest printed editions of each text dealt with. These earliest editions are often incunabula, i.e., prints anterior to 1501, and the historian of science, even if he is not specially interested in rare books as such, is nevertheless obliged to pay special attention to them.

Though his earliest investigations had led him to the examination of many incunabula problems, Dr. Sarton had never surveyed incunabula literature in general. Dr. Klebs' careful list of all the scientific and medical incunabula has now made it possible for the first time to consider such works as a group, from the statistical point of view. The results of his investigations will appear in *Osiris* (vol. 5). It is hoped that the studies of Dr. Klebs and those of Dr. Sarton will encourage other students to prepare careful analyses and discussions of the *contents* of incunabula. Thus far these precious volumes have been treated too much like relics and considered from the outside only, from the rather low point of view of the collector who cares for bibliographical rarities rather than for ideas, and treasures his books but does not read them.

Institute for the history of science. Dr. Sarton has published (in *Isis*, vol. 28, pp. 7-17, 1938) a third explanation of the need of such an institute and has outlined the principles of its organization. It should be noted that the rooms occupied by the Section of the History of Science of Carnegie Institution in the Widener Library of Harvard University already constitute, in a very modest way, such an institute. Many of the so-called institutes attached to European universities are far more rudimentary. A brief account of the facilities at present available may not be out of place.

According to a census made in December 1937, these rooms contain 3130 books, 8060 pamphlets (reprints, etc.), and some 40,000 bibliographical cards.

The books and pamphlets are of three kinds with regard to provenance. Some were bought by Dr. Sarton, others were given to the editor of *Isis*, finally 823 were bought by the Carnegie Institution. Of the latter, all but one were purchased during the period 1930-1937. The largest is naturally the group of books and pamphlets presented to the editor of *Isis*, though it represents only a part of the total number given to him, as many of these books are surrendered to other scholars who kindly undertake to review them in *Isis*.

In its totality this apparatus criticus is probably the richest of its kind anywhere, but its potential value is enormously increased by the fact that the rooms housing it are a part of the Harvard University Library or Widener Library, the largest university library in the world today. The total number of the books and pamphlets in that library (and departmental libraries connected with it) approaches four millions. These are completely and almost immediately available to the students using our apparatus. For example, the Harvard University Library has full sets of almost all the important scientific and learned periodicals and of the academic serials published throughout the world. Thanks to the generous cooperation of Harvard University and of the Carnegie Institution an instrument has been created which is already very good, and might be excellent if the space available for

books, archives, and students were increased, and means provided for its development and fuller utilization.

The rooms are always occupied by Dr. Sarton, Dr. Welborn, and Frances Siegel (secretary of the Section) and are often occupied by two or three other persons, students or scholars. They are used for the seminary in the history of science and learning in Harvard University, and are becoming more and more extensively recognized as a center of information for these studies. All the qualities of an institute are thus brought together, except stability and permanence.

Many members of the faculty and students, not only of Harvard University but of other colleges, as well as visiting scholars, come to consult our archives and are generally welcome. In addition, many inquiries are received by mail, and efforts are made to satisfy them as fully as possible.

Editing of Isis and Osiris. The "institutional," or pedagogical and normal, function of this section of Carnegie Institution appears very clearly in its editorial activities, for the journal *Isis* centralizes information concerning the history of science received from everywhere, classifies it, submits it to criticism, and redistributes it to whomever it may concern.

During the course of last year four numbers of *Isis* were published (74 to 77) completing volumes 27 and 28, plus volumes 3 and 4 of *Osiris*, devoted to the longer memoirs. A total of 2318 pages, 17 plates, 119 figures, containing 59 memoirs, 33 shorter notes, 96 reviews and 1655 bibliographical items.

It is worth noting that every memoir published in *Osiris* is the subject of a separate card printed by the Library of Congress. The same could not be done of course for *Isis*, the contents of which are far too abundant.

HISTORY OF GREEK THOUGHT—W. A. HEIDEL

During the year Dr. Heidel has been chiefly occupied with the history of Greek mathematics down to 400 B.C., or rather with the attempts made by various modern scholars to reconstruct the development. All these attempts are highly speculative, as is inevitable, because the available data are too few and, for the most part, too subject to suspicion. From the relatively few certain data, coupled with vague and discredited tradition that represents Pythagoras as the creator of Greek mathematics, it is now the fashion to attribute practically the whole development of the science to the Pythagoreans, despite the certain fact that most of the known mathematicians of the fifth century were Ionians, who, so far as we can discover, had no connection with Pythagoreans. Dr. Heidel has written a solicited article on this subject that should shortly be published in *Scientia*. Besides this study he has busied himself intensively with the medical and "Sophistic" literature of the fifth century, together with the Attic drama, which reflects the thought of the age. Practically the whole of his discussion of early Greek science and philosophy is now set forth in a first draft.

MOUNT WILSON OBSERVATORY

WALTER S. ADAMS, DIRECTOR
FREDERICK H. SEARES, ASSISTANT DIRECTOR

The number of sunspot groups observed during 1937, amounting to 537, was the largest since the establishment of the Observatory. It is probable that the maximum of the spot cycle was reached during the summer of 1937. The number of groups observed was 285 in the northern hemisphere, and 252 in the southern, the mean latitude of the spot zones being $16^{\circ}.7$, or $1^{\circ}.3$ higher than for the maxima of the last two cycles. Of 533 spots observed for polarity, 333 had regular polarity, 12 irregular, and 188 were unclassified. These observations have been carried on by Nicholson, Richardson, Hickox, and Edison Hoge.

Photographs of sunspot spectra in the region $\lambda 6600$ – $\lambda 8850$ show many new spot lines and an interesting reversed Zeeman pattern for the band lines of calcium hydride near $\lambda 7025$. The separations of these lines are from one-fourth to one-third those of neighboring atomic lines. The spectra of several spots have been photographed on successive days as the spots moved across the sun's disk, and will be used in photometric studies of the spectrum.

Measurements by Pettit of the energy-curve of the sun over the interval $\lambda 0.5 \mu$ to $\lambda 0.315 \mu$ with a 21-foot concave grating and a quartz photo-electric amplifier give absorption coefficients, by which energy measurements may be reduced to the continuous spectrum, ranging from 0.9 at $\lambda 0.5 \mu$ to 0.61 near $\lambda 0.39 \mu$. The energy-curve thus derived is in indifferent agreement with the black-body energy-curve.

Spectrograms of four bright chromospheric eruptions taken by Richardson with brief intervals between successive exposures indicate that the only lines apparently affected are H and K of calcium and the hydrogen lines of the Balmer series. Distinct emission can be observed at the positions of the lines $H\zeta$, $H\eta$, and $H\theta$.

An eruptive prominence observed by Hickox on March 20, 1938, reached the record height of 1,550,000 km, or into the general region of the outer corona. Its position was within 15° of the north pole of the sun. Analysis of its motions gave but three successive velocities, 67, 135, and 200 km/sec. An eruptive prominence observed by Pettit at the McMath-Hulbert Observatory on September 17, 1937, reached a height of 1,000,000 km and showed velocities of 28, 58, 186, 540, and 728 km/sec. The last two values exceed the parabolic velocity of escape at the corresponding elevations.

These observations indicate that the time interval within which a change of velocity can take place may be less than 45 seconds, and also that the velocity may be a multiple not of the preceding but of the second preceding value. Some apparent discordances, however, may be explained on the assumption that a change took place before the observations began. On the basis of a theoretical investigation Pettit concludes that radiation pressure from bright chromospheric eruptions cannot account for the observed velocities.

An extensive series of visual measurements of the percentage amount of plane polarization in light diffusely reflected by lunar and terrestrial materials has been completed by Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, and the results are being prepared for publication. A new alternating-current amplifier of special design is being used for the study of the polarization of moonlight and sunlight diffusely reflected by terrestrial substances.

Direct photography during the year has included a series of pictures at 4-second intervals of the total lunar eclipse of May 14, 1938; about 25 negatives of Finsler's comet taken in July and August 1937 by Christie; and planetary photographs at the coudé focus of the 100-inch telescope obtained on kodachrome film by Dunham.

Trigonometric parallax observations by van Maanen have added nine stars during the year to the list of those with photographic absolute magnitudes fainter than +10. Fourteen stars are now known with absolute magnitudes of +15.0 or fainter. The most frequent absolute magnitude among nearly 100 stars of low luminosity is about +12.

Studies of proper motions have included a comparison by van Maanen of some of the early photographs of fields in the Selected Areas taken nearly 30 years ago with recent plates of the same fields. Measures indicate that the probable errors on the early plates are too large to justify their use for accurate determinations of proper motions. A valuable addition to our knowledge of the proper motions of certain important classes of stars which have been under spectroscopic investigation has been made by R. E. Wilson, who by the use of various recent observations has derived accurate proper motions for more than 700 objects.

Important progress has been made by Seares and Miss Joyner in the determination of additional standards of magnitude among stars north of +80°. The larger number of stars now available should provide plate corrections which may make it possible to include in the reduction some of the earlier long-exposure photographs.

Final photographic magnitudes to the limit 21 have been completed by Baade for Selected Area 68, and the photovisual scale in the same area to magnitude 20 is under investigation. Tests on stars between magnitudes 13 and 17 show that the adopted photographic absorption of the platinum half-filter used in this work conforms to the international photographic scale.

Stebbins and Whitford have completed a survey of the colors derived from photoelectric observations of about 1300 B-type stars north of -40°. In the case of strongly colored B stars they find that the reddening varies as λ^{-1} instead of λ^{-4} , as would be the case for Rayleigh scattering by small particles. Measures of the colors of A0 stars within 10° of the north pole show that the obscuration present is due to material more than 100 but less than 250 parsecs distant, and produces a mean color excess of about 0.10 magnitude.

Additional photometric investigations have included Christie's measurements of the integrated photographic magnitudes of globular clusters, now including about 80 objects, and numerous observations of individual stars by various observers.

A statistical study by Strömberg of the mean absolute magnitudes and dispersions in magnitude of stars of types G8-K2 and G0-G7, as derived from trigonometric parallaxes, has been completed. The grouping of the stars was according to reduced proper motion. The relation between H and M shows a clear distinction between supergiants, giants, and dwarfs. The spectroscopic absolute magnitudes have in general been found to be nearly correct and have a mean error of between 0.5 and 0.6 magnitude. A grouping of the stars according to spectroscopically determined absolute magnitudes gave results very similar to those obtained from the grouping based on reduced proper motion. A separate study of the dwarf stars of types G0-G7 and G8-K2 indicates that the dispersion in absolute magnitude is apparently underestimated in the spectroscopic results.

In the field of stellar spectroscopy radial velocities have been determined and published for 600 stars, mainly of advanced types of spectrum, and for 70 stars of early type investigated primarily for interstellar lines. Several bright stars have been observed for small variations in velocity, and a series of spectrograms of α Boötis has been used for a determination of the solar parallax.

The radial-velocity curves of 128 Cepheid variables, of which 105 were previously unobserved, have been derived and published by Joy, and the results have been studied statistically. These stars are of great importance because of their high luminosities, their distribution, and the valuable data they afford for investigations of solar motion, galactic rotation, and absorption of light in space.

Two results of interest with the coude spectrographs have been the identification of many lines of ionized elements in the extreme ultraviolet region of the spectra of O- and B-type stars by Adams and Dunham, and the discovery of the double character of a number of lines in the spectra of α Orionis, α Scorpii and other supergiant M-type stars. The principal double lines observed are due to $Mn\ I$, $Cr\ I$, $Ca\ I$, $Sr\ II$, and $Ba\ II$. All originate from the ground state of excitation of the neutral or ionized atom. The lack of symmetry of the components and their character make it improbable that the doubling is an effect of reversal.

Observations of variable stars have included many of types Me and Se, irregular variables, and those of the RV Tauri and RR Lyræ types. W Canum Venaticorum has been followed in detail. The spectra of SU Ursæ Majoris and X Leonis are practically continuous at maximum of light. The components of the emission lines of α Ceti photographed with high dispersion at maximum of light show great changes in relative intensity with phase.

Many of the faint older novæ have been photographed during the year by Humason and Joy. Some show a continuous spectrum with no visible emission lines, while others have emission present. Their color in all cases is distinctly blue. The densities of Nova Persei (1901) and Nova Aquilæ (1918) have been calculated on the basis of their measured distances and the assumption of the temperature of an O-type star and prove to be 220 and 70 times the density of the sun, respectively. A value of 60 times the sun's density is found for 14 other old novæ whose distances are less certain.

Measurements of the intensities of the interstellar lines of calcium and

sodium have led Dunham to attempt quantitative determinations of the numbers of atoms of these elements in interstellar space. The faint interstellar line of neutral calcium at $\lambda 4226$ indicates the presence of approximately 2500 singly ionized calcium atoms for each neutral atom. About 20 electrons per cubic centimeter are required to maintain the ionization of calcium at the observed level. On this basis calculation gives the following very tentative values for the total concentration per cubic meter of space: Electrons, 20,000,000. Atoms, *Na*, 6; *K*, 0.2; *Ca*, 0.1; *Ti*, 0.001. Merrill and Sanford have derived a value of 1.6 for the ratio of D2 of sodium to K of calcium and conclude the presence of about three times as many atoms of singly ionized calcium as of neutral sodium.

Sanford has succeeded in measuring the components of double interstellar lines in five stars additional to those previously known. In three cases the total absorption of the components has been determined.

Two probable interstellar lines at $\lambda 6203.0$ and $\lambda 6263.0$ have recently been discovered by Merrill and O. C. Wilson. Their work also provides further evidence that the wide, diffuse feature at $\lambda 4430$, originally noted by Beals and Blanchet, is of interstellar origin.

From an analysis of the radial velocities of Cepheid variables as applied to galactic rotation Joy has found the following elements: solar orbital velocity, 296 km/sec; longitude of center of rotation, $326^{\circ}3$; radius of sun's orbit, 10,000 parsecs. The lack of observations of stars in the southern hemisphere greatly reduces the weight of the solutions. A correction for space absorption of 0.85 magnitude (photographic) per 1000 parsecs was derived and applied.

The conclusion of Plaskett and Pearce that interstellar matter shares in galactic rotation is strongly supported by an extensive study of detached lines by Merrill and Sanford. For the constants of galactic rotation they find: $l_0 = 329^{\circ}$; $A = 14.8$ km/sec per 1000 parsecs. The nearer gases give a somewhat larger value of A than those at greater distances, a result possibly due to a decrease in the average density of interstellar matter at distances greater than 1000 parsecs from the sun.

A sharp absorption line of considerable strength at $\lambda 3888$ found by O. C. Wilson in the spectra of θ^1 C and θ^2 Orionis and other stars embedded in the Orion Nebula is probably to be ascribed to the helium atoms of the nebula. The line is superposed upon the broad diffuse $H\zeta$ absorption characteristic of the stars. Measures indicate a systematic velocity of approach relative to the emission lines of the nebula, a difference possibly due to the pressure of radiation from the stars acting upon the helium atoms of the nebula.

Numerous miscellaneous stellar spectroscopic observations have been in progress. Among these are included: spectra of R and N stars by Sanford and of various peculiar spectra by Merrill; a study of the lines of ionized barium in early-type stars by Miss Burwell; radial velocities of faint stars of large proper motion by Adams and Joy, who have recently published a list of 25 stars with velocities exceeding 75 km/sec; radial-velocity observations of stars in the Selected Areas by Strömberg; the spectrum of the white dwarf AC + $70^{\circ}8247$ by Minkowski, in which microphotometer tracings

show extremely wide, shallow absorption features at $\lambda 4135$ and $\lambda 4475$; the spectrum of a seventeenth-magnitude A-type star in the field of the old nova B Cassiopeiæ by Humason; and the discovery by O. C. Wilson of a bright emission line in the wing of H in the spectrum of α Boötis which is probably due to H ϵ . Measurements of microphotometric tracings of stellar spectra have been continued by Dunham and Miss Carlson and other members of the staff.

Many remarkable results have attended the continuation of Baade's photography of obscured regions in the sky through red filters, especially in the direction of the galactic center. The greater space-penetrating power of red than of blue light has resulted in many cases in showing vastly greater numbers of stars, marked differences in the patterns of the obscuring clouds, and the presence of globular clusters and nebulae hardly visible on photographs in blue light. For example, NGC 6357, of which only one or two small wisps appear on ordinary photographs, is found on the red plates to be an outstanding object rivaling in size the Orion Nebula and Messier 8. In the course of these observations a variable sky fog which appeared on the photographs and proved to be a function of zenith distance is provisionally ascribed to the red auroral lines in the earth's atmosphere. This question is under investigation.

On photographs taken by Baade in December the preceding half of the variable nebula NGC 2261 appeared with its usual intensity, but the following half was completely obscured. Apparently an obstruction near the exciting star, R Monocerotis, through which the boundary of the illuminated area very nearly passed, threw a shadow upon the following half of the nebula. Fragmentary observations in January and February showed that the "shadow" had moved from west to east at the rate of 0'08 per day, having lost its straight-line appearance in the interval.

Direct photography of planetary nebulae was continued by Dr. Duncan, who investigated 15 objects. No new ultraviolet envelopes were found, but interesting new details were observed in several nebulae. Minkowski obtained numerous spectrograms with the interference spectrograph of the planetary NGC 6826 and found a distribution of radial velocities such as might be expected in a nebula rotating around its minor axis.

An extensive program completed by Hubble during the year was that of obtaining satisfactory photographs with the large reflectors of the 800 extragalactic nebulae in the Shapley-Ames catalogue, north of -30° and of photographic magnitude 12.9 or brighter. This work has required the cooperation of several observers over a period of years. The collection now includes about 2000 NGC objects and nearly 1000 given in the IC. The material is under investigation for sequences of classification, frequencies of various types, and small-scale distribution of nebulae.

About 60 new short-period Cepheids have been identified in a cooperative study by Hubble, Baade, and Humason of the four relatively near nebulae M 31, M 33, NGC 6822, and IC 1613. Long-exposure photographs with the 100-inch reflector were made on each nebula on 10 to 12 successive nights. The magnitudes are being based upon the scale for very faint stars estab-

lished by Baade in Selected Area No. 68. Results have been essentially completed for the variables in IC 1613.

Spectrographic observations by Humason have included determinations of apparent velocities and spectral types for 21 extragalactic nebulae. These consist of members of clusters and groups, and several large, resolved, near-by nebulae. A spectrogram of NGC 4111, taken with a dispersion double that previously used on this object, is measurable to a distance of 20" from the nucleus along the major axis. This dispersion will be used in a study of the rotation of this nebula and a few others.

For the first time it has been possible during the past year to undertake a systematic study of those remarkable objects, the supernovae in extragalactic nebulae, with adequate photometric and spectroscopic apparatus. As distinguished from ordinary novae, which are found fairly frequently in extragalactic nebulae, supernovae occur but rarely and are of a different order of magnitude. They represent a release of energy far beyond that of any other known phenomenon, a luminosity of the order of 10^9 suns having been attained by one of the two objects recently investigated.

The two supernovae in IC 4182 and NGC 1003 discovered by Dr. Fritz Zwicky, of the California Institute of Technology, with the 18-inch Schmidt telescope on Mount Palomar had magnitudes of 8.6 and 12.8 at maximum and were the brightest recorded since Z Centauri (1895). The supernova in NGC 1003 was discovered before maximum and that in IC 4182 probably a few days after maximum. Definitive light-curves were established by Baade and were found to be similar for the two stars and to follow the normal pattern. The two nebulae are resolved, late-type spirals, with distances, estimated from their brightest stars, of 0.9×10^6 parsecs for IC 4182 and 1.5×10^6 parsecs for NGC 1003. The corresponding photographic absolute magnitudes were -16.6 for the supernova in IC 4182 and -13.2 for that in NGC 1003.

About 30 spectrograms of the supernova in IC 4182 were obtained, mainly by Minkowski, beginning on August 29, 1937, about nine days after maximum, and 10 spectrograms of that in NGC 1003, beginning on September 11, 1937, about two days before maximum. The spectra of the two stars at corresponding phases were closely comparable except for minor details, and differed from those of any other known stars, including ordinary novae.

Wide, partially overlapping emission bands form the recorded portion of the spectrum between $\lambda 3700$ and $\lambda 6800$. In the blue region the chief feature was a strong band in the neighborhood of $\lambda 4600$, but some fainter bands were also present. After the first three weeks a fairly stable pattern developed which persisted with minor changes throughout the period of the observations. The entire pattern, however, shifted gradually toward the red, the displacement amounting in June 1938 to about 100 Å for the star in IC 4182, and in January 1938 to about 70 Å for that in NGC 1003.

The behavior of the bands in the red ($\lambda > 5000$) was very different from that of the bands in the blue. They varied rapidly, appearing and disappearing somewhat like the emission bands in ordinary novae. In February 1938, when NGC 1003 could not be observed, two narrow bands, each about 40 Å wide, appeared at $\lambda 6299$ and $\lambda 6359$ in the spectrum of the supernova in IC

4182. The stronger band at $\lambda 6299$ was still prominent in June 1938 when all the other bands in the red had nearly disappeared.

The identification of the emission bands in the spectra is a difficult problem, especially in view of the red shift. No evidence whatever has been found of the presence of hydrogen, and at present the only plausible identification is that of the two narrow red bands with the forbidden lines of O I at $\lambda 6300$ and $\lambda 6364$. On the assumption of expanding shells the widths of the individual bands suggest velocities not exceeding 3000 km/sec.

An extensive study of the spectrum of europium has been completed by King in the physical laboratory. It includes wave-length measurements of about 3750 lines between $\lambda 2100$ and $\lambda 10165$, nearly three times the number previously known; their separation into lines of the neutral and the ionized atom; and their temperature classification from results with the electric furnace. The hyperfine structure of most of the europium lines and the great range in their intensities have caused unusual difficulty in the investigation of this spectrum.

A comparison of his results on europium with the solar spectrum has led King to identify 20 lines of the neutral atom, all very strong in laboratory spectra, with faint, unidentified solar lines. As would be expected, the lowest-temperature (ultimate) lines appear in sunspot spectra and the higher-temperature lines in the spectrum of the solar disk. The only lines in the solar spectrum previously identified as belonging to neutral atoms of the rare earths were two lines of ytterbium. The new results have also increased the number of identified lines of singly ionized europium in the solar spectrum from the 5 given in the *Revised Rowland Table* to 27.

King has also commenced a study of the spectrum of gadolinium, which should greatly increase the number of lines now known. A preliminary examination of the spectrograms shows a very definite grouping of the lines with temperature.

The spectra of a number of elements have been photographed by Anderson in the vacuum spark in the region $\lambda 4500$ – $\lambda 7000$, with the use of two commercial condensers, each of one-half microfarad capacity and 50,000 volts, which have replaced the former glass-plate condensers. The exposure times required are immensely longer than for the ultraviolet region, and the deformation of the spark terminals has presented a serious problem. Attempts are being made to overcome these difficulties.

Tests made by Babcock about a year ago showed that the screw of the new ruling machine was undergoing spontaneous changes of form which made the construction of a new screw necessary. This has now been cut and the lapping is under way. Especial attention was given to the selection of the material and exacting tests were made before this work was begun.

Babcock has undertaken the measurement with a photronic cell of the luminous efficiency of several gratings ruled at Mount Wilson and elsewhere. The brightest grating investigated was one ruled at Mount Wilson on speculum metal and subsequently aluminized. It seems probable, however, that evaporated aluminium ruled directly could be made to return more light than aluminium superposed on an existing ruling. Gratings can now be ruled which will return from 50 to 60 per cent of the incident, visible, monochro-

matic radiation in one order. An interesting result of these measurements is the extent of the dependence of the intrinsic brightness of the spectrum in a given order upon the angle of incidence. In some cases the variation may be as great as twofold.

The partial reconstruction of two important instruments has been in progress during a portion of the year. The 60-foot tower telescope, the first instrument of this type ever built, is being remodeled to provide for greater convenience in operation and more constant use. The mountings of the cœlostat and second flat mirrors are being redesigned, a new drive installed, and many features added to provide for automatic registration of the sun's image throughout the day. The mounting of the 10-inch photographic telescope is also being remodeled and a photovisual objective has been designed to aid in the photography of objective-prism spectra in the yellow and red regions.

STAFF

The death on February 21 of Dr. George E. Halé, founder of the Observatory, Director from 1904 to 1923, and Honorary Director from that time onward, brought to a close a life of remarkable accomplishment in the domain of American and international science. A brilliant investigator whose discoveries in solar physics marked an epoch in this field of research, his name will be equally remembered for the many great institutions which he conceived and established, and for the breadth of his outlook upon the progress of science and its part in human life. In the field of astronomy the Yerkes, Mount Wilson, and Palomar Observatories, and in national and international science the National Research Council and the International Council of Scientific Unions form but a part of Dr. Hale's contribution to scientific development and the agencies for dealing with it most effectively. His wisdom in planning the work of the Mount Wilson Observatory, his appreciation of the importance of astrophysics and of the physical method of attack upon scientific problems, and his constant encouragement of his associates to undertake investigations freely and independently with every facility which he could afford them, were but a few of the many characteristics which he showed so strongly during the years of his conduct of the Observatory. Finally, no one could be associated with him without acquiring a deep personal affection for him, based upon his charm, his generosity and modesty, his enthusiasm, and his great intellectual gifts. The influence of his life will continue as a cherished heritage at the Observatory.

Two other members of the staff have died during the past year, Dr. Francis G. Pease on February 7, and Dr. Sinclair Smith on May 18. Dr. Pease was associated with the Observatory from its foundation, and his contribution to its work, especially in the design of instruments and in theoretical and practical optics, was very great. He was largely responsible for the completed design of the 100-inch telescope and many other major instruments. A skillful and accurate observer, he is best known for his measurements of stellar diameters with the interferometer, his collaboration with Dr. Michelson in determining the velocity of light, and his admirable work in stellar and lunar photography.

Dr. Smith was associated with the physical laboratory for several years, where his skill and ingenuity led to many researches of interest. He also undertook observations in the difficult field of nebular spectroscopy with excellent success. Together with Dr. Pease, Dr. Smith devoted a large part of his time during recent years to problems relating to the construction of the 200-inch telescope, and the loss of both of these able and experienced designers will be felt severely in connection with this great project. To their associates at Mount Wilson both members of the staff had endeared themselves greatly through their unfailing friendliness and courage, and their cordial willingness to assist at all times with the valuable technical knowledge at their disposal.

Dr. Walter S. Adams, Director, has attended to the numerous duties relating to the administration of the Observatory and continued his investigations in stellar spectroscopy, giving much time to problems best studied with the aid of high-dispersion spectrograms. Dr. Frederick H. Seares, Assistant Director, has aided in the administration and continued his editorial supervision of the Observatory publications. He has also continued his researches on standard magnitudes.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has finished and brought together his extensive results on the wave lengths and the temperature classifications of lines of the rare earth europium. Dr. John A. Anderson has continued to serve as Executive Officer of the 200-inch telescope project. The remainder of his time he has given to laboratory investigation of the vacuum spark. Dr. Edwin Hubble has completed an extensive observing program devoted to the brighter nebulae and has begun a detailed analysis of these data. Dr. Walter Baade has given special attention to photometric problems connected with the two supernovae discovered in extragalactic systems by Dr. Fritz Zwicky of the California Institute of Technology and to a continuation of his program of photographing star clouds and nebulae with the aid of red filters. Dr. Paul W. Merrill, Dr. Roscoe F. Sanford, and Dr. Olin C. Wilson have continued their cooperative investigation of problems relating to interstellar matter besides carrying on many other studies in stellar spectroscopy. Dr. Seth B. Nicholson has remained in general charge of solar investigations, and during the year has completed the revision of the manuscript for the volume "Magnetic observations of sunspots, 1917-1924." Dr. Edison Pettit has given the greater part of his time to the study of solar prominences. Three months of the summer of 1937 were spent at the McMath-Hulbert Observatory in observations of this kind. Mr. Harold D. Babcock has been engaged in the measurement and study of lines in the infrared solar spectrum and in problems connected with the ruling machines. Professor Alfred H. Joy, Secretary of the Observatory, has published his observational results on the radial velocities of Cepheid variables and has discussed their bearing on the problem of galactic rotation. Dr. Francis G. Pease continued his observations with the 50-foot interferometer and his work on the 200-inch telescope until his untimely death on February 7, 1938. Dr. Adriaan van Maanen, as for many years past, has devoted his time to the measurement of trigonometric parallaxes

and of proper motions. Dr. Ralph E. Wilson, who joined the staff of the Observatory January 1, 1938, has also been occupied with proper motions, which he has derived for variable stars and for stars of infrequent spectral type. Dr. Theodore Dunham, Jr., has worked largely with high-dispersion stellar and solar spectra, and has given much time to problems of instrument design. Mr. Milton L. Humason has systematically studied the spectra of old novæ, obtained spectrograms for 21 extragalactic nebulæ, and begun a study of the rotation of these nebulæ. Dr. Gustaf Strömberg has continued his observations of the spectra of stars in Selected Areas and his statistical investigations of stellar luminosity. Dr. Robert S. Richardson has given his time largely to the study of chromospheric eruptions and has begun a study of their spectra. Dr. Rudolph Minkowski has continued his spectrographic studies of galactic nebulæ and has obtained a notable series of spectrograms of the two supernovæ discovered a year ago. Dr. Sinclair Smith, engaged mostly with problems of instrument design, was transferred wholly to the 200-inch telescope project on January 1, 1938. His death occurred four and one-half months later, on May 18. Mr. William H. Christie has photographed Finsler's comet and carried on miscellaneous spectroscopic and photometric observations. Mr. Joseph Hickox has continued as regular solar observer on Mount Wilson. Mr. Hickox and Mr. Christie together have given the Friday evening public lectures delivered regularly at the Auditorium on Mount Wilson. Mr. Edison Hoge has served as part-time solar observer and carried on the miscellaneous photographic work of the Observatory.

In the Computing Division Miss Louise Ware has assisted both Dr. Nicholson and Dr. O. C. Wilson in solar and stellar investigations. Mrs. Elizabeth Sternberg Mulders has continued the preparation and compilation of various data relating to solar activity. Mr. E. F. Adams has handled part of the regular compilations of solar data and made measurements and reductions of solar spectrograms. Miss Mary C. Joyner has collaborated with Dr. Seares in measurements and computations relating to the extension of the Polar Sequence. Miss Cora G. Burwell has assisted in various stellar spectroscopic investigations, especially those of Dr. Merrill, and has studied the intensities of ionized barium lines in early-type spectra. Miss Myrtle L. Richmond has continued the measurement and reduction of the records of ultraviolet solar radiation and done much miscellaneous computing. Miss Ada M. Brayton and Miss Louise Lowen have aided in many phases of the stellar spectroscopic work, and Miss Lowen has also assisted Dr. van Maanen in his work on parallaxes and proper motions. Miss Dorothy J. Carlson has divided her time between computations for Dr. Dunham and compilations relating to nebulæ for Dr. Hubble. Mrs. Mary F. Coffeen, who was appointed on October 18, 1937, has assisted Mr. Babcock in work on the infrared solar spectrum. Dr. R. M. Langer served as part-time assistant at the Solar Laboratory until August 1, 1937. Miss Elizabeth Connor, Librarian, has continued to assist in the editorial work of the Observatory.

Dr. Henry Norris Russell, Research Associate of the Carnegie Institution and Director of the University Observatory, Princeton, has continued an in-

vestigation of the errors of spectroscopic parallaxes. Dr. Joel Stebbins, Research Associate of the Carnegie Institution and Director of the Washburn Observatory, was in residence at the Observatory from July to October 1937 and again during June 1938, engaged in photoelectric measurements of early-type stars and other special objects. Dr. Albert E. Whitford aided in these measurements, partly as National Research Fellow and partly as a special assistant of the Observatory.

Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution, with the aid of Mr. Hamilton Wright, continued his measurements of the polarized radiation of the moon during the interval August 4 to September 15, 1937. He arrived again in Pasadena June 21, 1938, in preparation for systematic photography of the moon's surface throughout an entire lunation. Dr. Frank E. Ross, of the Yerkes Observatory, was in Pasadena from September 1937 until March 1938, engaged in optical computations and tests on correcting lenses for the Mount Wilson reflectors and the 200-inch telescope. Dr. John C. Duncan, Director of the Whittin Observatory, made observations with the 60-inch and 100-inch reflectors between July 3 and August 26, 1937. Dr. Walter T. Whitney, of Pomona College, has served as volunteer observer at intervals throughout the year, devoting his time to photometric questions. Dr. Robert King, of the Massachusetts Institute of Technology, worked in the Physical Laboratory during the summer of 1937. Dr. Lyman Spitzer, Jr., of Princeton University, also spent the summer at the Observatory, engaged in studies of microphotometer records of spectra. Mr. Raymond Wilson arrived at Mount Wilson in June for work as volunteer assistant with the 50-foot interferometer. Mr. William Miller, of Paramount Pictures, Inc., has served as a volunteer observing assistant for Dr. Merrill. Mrs. Charlotte Moore Sitterly spent two weeks at the Observatory in August 1937 in discussions with Mr. Babcock relating to the infrared solar spectrum. The Observatory has also been visited by many others with whom the members of its staff have had profitable discussions, among them, Dr. J. A. Fleming and Dr. A. G. McNish of the Department of Terrestrial Magnetism, Dr. Ejnar Hertzsprung, Director of the Observatory at Leiden, Dr. Knut Lundmark, Director of the Observatory at Lund, Dr. R. W. Wood of Johns Hopkins University, and Dr. E. A. Kreiken from Sumatra.

Dr. Adams, Dr. Nicholson, and Dr. Dunham attended the annual meeting and exhibit of the Carnegie Institution at Washington in December 1937. Dr. Nicholson and Dr. Dunham had the chief responsibility for the preparation of the exhibit from the Observatory. Dr. Dunham delivered the Institution lecture given regularly on the occasion of the annual meeting. Dr. Seares delivered, in Washington, on April 19, 1938, the fourth of the Elihu Root lectures, given under the auspices of the Carnegie Institution. At various dates in June and July 1938, Messrs. Adams, Baade, Humason, Merrill, Stebbins, Strömberg, and van Maanen left Pasadena to attend the meeting of the International Astronomical Union to be held at Stockholm on August 3-10. Dr. Russell, already abroad, was also planning to attend the meeting.

OBSERVING CONDITIONS

The number of observing nights during the year was a little below the 25-year average. The winter was mild, with a minimum temperature of 19° F on February 13, 1938, and a total snowfall of only 15.5 inches. The maximum temperature, 97° F, occurred on August 19, 1937. The total precipitation of 58.88 inches replaces last year's total of 53.35 as the second highest seasonal total recorded for Mount Wilson, and closely approaches the highest, 60.51 inches for 1921-1922. The seasonal average for 34 years is 32.94 inches. The meteorological event of the year was the rainstorm extending over the last two days of February and the first three of March 1938. The precipitation, including a half-inch of snow on the last day, was 26.23 inches, 45 per cent of the total for the season. The storm set a record for a 24-hour interval: 12.81 inches, from 9 p.m. March 1 to 9 p.m. March 2. The Angeles Crest Highway leading to Mount Wilson was carried away in a dozen places and at many other points was blocked by slides. About two weeks were required for temporary repairs sufficient to permit emergency motor travel to the summit. The road was closed to the public for three months during the extensive reconstruction required.

During the year July 1, 1937, to June 30, 1938, stellar observations were made on 281 nights, of which 208 were wholly clear and 73 partly cloudy; solar observations were made on 293 days. The accompanying table shows the distribution of nights during which observations were made with the 60-inch reflector.

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1937:				1938:			
July.....	27	2	2	January.....	9	12	10
August.....	30	1	0	February.....	6	7	15
September.....	25	4	1	March.....	5	5	21
October.....	22	7	2	April.....	16	5	9
November.....	15	12	3	May.....	18	4	9
December.....	15	8	8	June.....	20	6	4
				Total.....	208	73	84
				Mean 25 years..	204	86	75

SOLAR RESEARCH

The routine program of daily observations of sunspots, prominences, and flocculi and the daily records of the intensity of ultraviolet radiation and of the direction and horizontal intensity of the earth's magnetic field have been continued.

Daily photographs of the sun have been sent semimonthly to the Naval Observatory to complete their record of the positions and areas of sunspots, which is published in the *Monthly Weather Review*. Reports of the daily number of sunspots and groups have been communicated weekly to Science

Service at Washington for publication in their bulletins of *Cosmic Data*. Duplicate spectroheliograms have been supplied regularly to the Kodaikanal and Meudon observatories as a part of the plan of cooperative solar observation. The approximate positions, field strengths, and magnetic classifications of all sunspots have been printed regularly in the *Publications of the Astronomical Society of the Pacific*. Estimates of daily character figures of solar activity from calcium and hydrogen flocculi have been sent to Commission 10 of the I. A. U. for publication in its *Bulletin for Character Figures of Solar Phenomena*. These estimates have also been published in *Terrestrial Magnetism and Atmospheric Electricity*. The data were compiled and prepared by Nicholson and Mrs. Mulders.

The positions and intensities of bright chromospheric eruptions have been communicated by Richardson to Commission 11 of the I. A. U. for publication in the *Bulletin for Character Figures* as a part of the cooperative program of solar observation with the spectrohelioscope.

Measurements of ultraviolet radiation by Pettit and Miss Richmond have also been published regularly in this *Bulletin*.

Estimates of the daily magnetic character figures have been made by E. F. Adams for publication in *Terrestrial Magnetism and Atmospheric Electricity*.

The year has seen the completion of an investigation of long standing by Hale and Nicholson, "Magnetic observations of sunspots, 1917-1924," a quarto volume in two parts, to be issued as Carnegie Institution Publication No. 498. The manuscript went to the printer in April 1938.

SOLAR PHOTOGRAPHY

Solar photographs have been made by Hickox, Hoge, Nicholson, and Richardson on 268 days at the 60-foot tower telescope. Direct solar photographs are usually taken early in the morning and followed by spectroheliograms made at the 60-foot, the 18-foot, or the 7-foot focus, according to the quality of the seeing. The spectroheliograms with the 7-foot focus objective are on motion-picture film used in an automatic recorder, which is easily exchangeable with the plateholders and runs continuously unless larger spectroheliograms are being made or the spectrohelioscope is in use. The exposures are of from one to two minutes duration, separated by intervals of from one to two minutes; and within these limits the sun was under observation for an average of 6 hours on 268 days during the year. The approximate number of exposures of each kind was as follows:

Direct photographs.....	590
H α spectroheliograms of spot groups, 60-foot focus.....	440
H α spectroheliograms, 18-foot focus.....	1,500
H α spectroheliograms, 7-foot focus.....	28,000
K2 spectroheliograms, 18-foot focus.....	770
K prominences, 18-foot focus.....	870

SUNSPOT ACTIVITY

During the calendar year 1937, solar observations were made on 314 days, on all of which spots were visible. The monthly means of the number of groups observed daily during the past two and one-half years are given in the accompanying table.

Month	Daily number			Month	Daily number	
	1936	1937	1938		1936	1937
January.....	5.6	10.7	8.8	July.....	5.4	13.6
February.....	7.7	12.0	9.7	August.....	7.3	12.0
March.....	7.9	9.5	7.0	September.....	8.1	9.1
April.....	8.4	8.3	8.7	October.....	8.2	10.0
May.....	6.3	8.6	11.3	November.....	8.8	7.8
June.....	7.1	9.8	9.1	December.....	11.2	7.9
				Yearly average....	7.7	9.9

The mean number of groups observed daily in July 1937, namely 13.6, exceeded that in any month of the last two cycles. The number of groups in the northern hemisphere increased from 226 in 1936 to 285 in 1937; in the southern hemisphere, from 233 to 252. The total number of groups, 537, observed here in 1937 established a new record for Mount Wilson: 459 groups were observed in 1936, 450 in 1917, and 424 in 1927. The exact time of maximum activity cannot yet be stated with certainty, but it is unlikely that the activity in this cycle will exceed that of July and August 1937. The mean latitude of spot zones was $16^{\circ}7'$, $1^{\circ}3'$ higher than for the maxima of the last two cycles. The largest groups of the year, Nos. 5477 and 5578, which crossed the central meridian on July 28 and October 4, 1937, respectively, were among the six largest groups ever observed.

SUNSPOT POLARITIES

When possible, the magnetic polarities in each spot group have been observed at least once. The accompanying table indicates the number of spot groups classified from July 1937 to July 1938. "Regular" groups in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.....	163	4	93
South.....	170	8	95
Whole sun.....	333	12	188

SUNSPOT AND SOLAR SPECTRA

Nicholson, Hoge, and Hickox have photographed the sunspot spectrum from $\lambda 6600$ to $\lambda 8850$ with the 75-foot spectrograph at the 150-foot tower telescope through polarizing apparatus suitable for the study of Zeeman displacements. Many new spot lines are recorded on these spectrograms. The band lines of calcium hydride near $\lambda 7025$ were found to have reversed Zee-

man patterns, with separations from one-fourth to one-third those of atomic lines in the same region. The lines in the primary band of titanium oxide at $\lambda 7054$ have normal Zeeman patterns with displacements of the same magnitude as those of the calcium hydride lines.

Spectrograms of several large stable sunspots have been obtained by Richardson at the 150-foot tower for use in the photometry of the spot spectrum. Four selected regions were photographed on successive days, when the observing conditions were excellent, as the spot moved from the east to the west limb. Much information concerning the structure of sunspots may be obtained from spot spectrograms taken in this way. The plates have not yet been measured.

The faintness of rare-earth lines in the solar spectrum is well known, and most of those hitherto identified belong to the ionized atom. With the aid of his recent laboratory data on europium (see pp. 204-205), King has been able to identify more than 20 of the neutral lines of this element with faint solar lines and to increase the known singly ionized europium lines in the sun from 5 to 27.

INFRARED SPECTRUM OF THE SOLAR DISK

Study of the spectrograms on hand has been completed by Babcock and specifications for the plates still required have been determined. The reduction of the spectrograms has been shortened by using tables of the coefficients appearing in the formulæ. The equipment in the Government Building used for most of the observations has been of great service, but the lack of a telescope imposed serious limitations. Transfer of the work to the Hale Solar Laboratory has therefore given it fresh impetus.

The 150-foot focus arrangement of the excellent reflecting telescope at the Laboratory has been put into commission, and the 75-foot spectrograph has been arranged to obtain the spectrograms of the center and the limb of the disk that are so much needed. The 21-foot concave grating formerly used in the Government Building has been remounted at the Solar Laboratory in a modified Eagle arrangement, where it may be used with any of the solar images provided by the telescope. Preliminary observations with this apparatus, now nearly in final form, indicate a satisfactory efficiency.

ULTRAVIOLET ENERGY-CURVE OF THE CONTINUOUS SOLAR SPECTRUM

The energy-curve of the sun has been measured by Pettit with the 21-foot concave grating and a quartz photoelectric amplifier over the interval $\lambda 0.5 \mu$ to 0.315μ in steps of 0.1μ . The area under an intensity-curve divided by the area under a line drawn through the point of highest deflection gives the absorption coefficient of the solar spectrum with which energy measurements made thermoelectrically may be reduced to the continuous spectrum. The values range from 0.9 at $\lambda 0.5 \mu$ to 0.61 near $\lambda 0.39 \mu$. Correction with the aid of these ratios modifies the form of the energy-curve but does not greatly improve its agreement with the black-body energy-curve.

CHROMOSPHERIC ERUPTIONS

Arrangements to photograph the spectra of bright eruptions in the chromosphere with the 60-foot tower telescope have been made by Richardson. The sun is kept under observation with the spectrohelioscope. When an eruption

starts, the spot is identified and the beam transferred to a mirror system that gives a 7-inch image. Exposures are then made at intervals of a few seconds in the second order of a concave-grating spectrograph.

Four eruptions of intensity 1 or 2 have thus far been observed on the disk, and their spectra have been photographed from $\lambda 6600$ to $\lambda 3400$. The only lines apparently affected on these exposures are the Balmer series and the H and K lines of calcium. Emission can be distinctly seen in $H\zeta$, $H\eta$, and $H\theta$. None of these hydrogen lines has been definitely identified in the normal solar spectrum. The intensity of the emission from $H\alpha$ to $H\epsilon$, inclusive, is very nearly the same as that of the continuous spectrum near the lines.

ERUPTIVE PROMINENCES

An eruptive prominence observed by Hickox on March 20, 1938, rose in 2^h34^m to the record height of 1,550,000 km, or 1.12 solar diameters, thus showing definitely that prominence material may reach the regions of the outer corona. The prominence appeared within 15° of the north pole of the sun, an unusual location for these objects. Analysis of the motions gave only three successive velocities, 67, 135, and 200 km/sec.

Pettit spent three months of the summer of 1937 at the McMath-Hulbert Observatory, collaborating with Mr. R. R. McMath in the study of prominences. Seven eruptive prominences were observed with the motion-picture equipment, making a total of 9 for the observing year, the largest number ever observed; the average for 50 years is one per year. The prominence observed at Lake Angelus on September 17, 1937, rose to a height of 1,000,000 km, with velocities of 28, 58, 186, 540, and 728 km/sec. The last two values exceed the parabolic velocity at the corresponding elevations and are the highest yet observed in prominences. The observations of this prominence reduce the time interval required for a velocity-change from the previous estimate of 5 or 10 minutes to less than 45 seconds.

The first law of motion of eruptive prominences is now abundantly verified. The second law, that any velocity is a small multiple of the preceding velocity, must be modified, however; occasionally a velocity is a multiple not of the preceding but of the second preceding value. Some apparent discordances can thus be explained on the assumption that in certain cases a change of velocity occurred before observations began.

Pettit has shown that, because of the Milne effect, we cannot assume a balance of light-pressure and gravity. With an initial velocity of 10 km/sec, a value very common in quiescent prominences, high velocities would develop in a few minutes; hydrogen and ionized calcium would tend to separate; and the character of the motion would be unlike that observed. As a propellant, radiation pressure from bright chromospheric eruptions seems to be an impossibility.

PHENOMENA OF PROMINENCES

Continuous observation of an active prominence over a considerable period occasionally reveals faint streamers, unconnected with the prominence, entering the center of attraction from high up in the coronal region with velocities of about 150 km/sec. About a dozen of these "coronal" prominences have been observed at Lake Angelus and five have been measured in detail.

Over an active sunspot group small, nearly round masses of chromospheric matter occasionally shoot out and, unlike the surges, do not return. These "ejections" are usually very faint, many being at the limit of vision on the films. Aside from surges and ejections, all motions in sunspot prominences are downward to the spot.

Ordinarily, streamer formations above a sunspot are preceded by the appearance of a bright, nearly round cloud, which feeds the streamers extending from one side of the cloud to the spot area. Sometimes the cloud elongates and feeds streamers from both ends, the prominence matter moving down both branches of the loop. Such loop formations are frequently seen over sunspot groups (class IIIb prominences). Measures of 94 streamers in active and sunspot prominences continue to show that the first, and in many cases the second, law of prominence motion applies.

LUNAR AND PLANETARY INVESTIGATIONS

SURFACE FEATURES OF THE MOON

Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, has completed the series of visual measurements of the percentage amount of plane polarization in light diffusely reflected by lunar and terrestrial materials and is now preparing the report on the results. To study the polarization of moonlight and of sunlight diffusely reflected by terrestrial substances, a new high-gain, alternating-current amplifier has been constructed in the laboratory of the Department of Terrestrial Magnetism from designs by Mr. Ellis Johnson of that Department. The instrument is used with a rotating Nicol prism (10 cycles per second) and furnishes an independent check on visual measurements. Preliminary tests indicate that it operates satisfactorily and has adequate sensitivity for the measurement of the intensity of the polarized component of the incoming beam; it also measures the total intensity of the incoming beam, but with smaller precision.

Dr. Wright is planning to photograph the lunar surface at brief intervals throughout the full lunation beginning June 27, 1938. The photographs will be made at the Newtonian focus of the 100-inch reflector with the aid of a zero corrector, which functions extremely well over the spectral range $\lambda 5000$ – $\lambda 6000$, and will form the basis for a topographic reconnaissance map of the central portion of the moon.

MOTION PICTURE OF LUNAR ECLIPSE

With the cooperation of Paramount Pictures, Inc., who supplied the camera, film, and processing, Christie and Mr. William Miller photographed the moon at 4-second intervals during the total lunar eclipse of May 14, 1938. The exposures, ranging from 0.02 to 2 seconds, were made with the 10-inch Cooke refractor, which gives a satisfactory scale for projection.

FINSLER'S COMET

Finsler's comet, whenever visible during July and August 1937, was photographed by Christie with the 10-inch telescope. The series of about 25 negatives shows the rapid changes in the form and the structure of the tail now recognized as characteristic of comets when close to the sun.

PLANETARY PHOTOGRAPHY

Dunham has continued his experiments in planetary photography at the 250-foot coudé focus of the 100-inch reflector mentioned in last year's report. Kodachrome film has been used to obtain photographs in color.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES

As for several years past, van Maanen has concentrated his parallax work largely on stars suspected of having very faint absolute magnitudes. During the year nine stars have been added to the list for which the photographic M is fainter than $+10$. One of these, vM,W No. 112, has $M = +15.0$. Of the 116 stars supposedly of low luminosity which are now finished, 5 have given negative parallaxes and 15 are companions. Omitting these, van Maanen finds the distribution of absolute magnitudes to be as shown in the accompanying table.

Photographic M	No. stars	Photographic M	No. stars
$< +9.0$	8	13.0-13.9.....	18
9.0- 9.9.....	6	14.0-14.9.....	9
10.0-10.9.....	11	15.0-15.9.....	8
11.0-11.9.....	15	$\geq +16.0$	2
12.0-12.9.....	20		

Including vM,W No. 112, we now know 14 stars with photographic absolute magnitude equal to or fainter than $+15.0$; three of these are companions.

An absolute parallax of $-0''.012$ has been found for SS Cygni. Since last year's report gave $+0''.010$ for U Geminorum, it seems doubtful if stars of this type of variability can be considered as dwarfs, as has been suggested by Parenago and Kukarkin (*V. F. A., Gorki*, vol. 4, p. 249, 1934).

PROPER MOTIONS

Four Selected Areas, Nos. 60, 72, 91, and 92, have been measured by van Maanen for proper motion. In addition, No. 35 had been measured before. For each field two early exposures, made by Seares for his photometric work, were compared with two exposures taken recently at the Newtonian focus of the 60-inch reflector. The results of the measures of these five fields are as follows:

The probable errors of a final μ_a , μ_b , and μ for a star are $0''.0029$, $0''.0028$, and $0''.0038$, respectively, while for the 13 nebulae shown with good measurable images the errors are about twice as large. Since the mean motions of the fainter stars in a galactic latitude equal to the mean for the five fields may be expected to be $0''.010$ to $0''.015$, it is evident from the probable errors alone that the available material hardly warrants a major undertaking of measuring some 30,000 to 40,000 stars in the 135 Selected Areas for which early plates are available. For a possible reduction of the relative motions of the nebulae and the fainter stars, the results are even less promising owing

to the small number of the nebulae measurable on these plates and their relatively large probable errors.

Analysis of the motions according to magnitude and amount of proper motion shows further that the percentage of small motions (< 0.010) is only half of that found by Willis from a series of plates taken at the Cassegrain focus of the 60-inch reflector. This indicates that the probable errors in the measures of plates taken at the Newtonian focus are too large for these plates to be of great use. Finally, an attempt to derive the direction and the amount of parallactic motion for these faint stars gives no reliable result.

The main cause for these disappointing results is probably the fact that the early plates were not taken with astrometric measures in view. The hour angles are large, in the mean 27° (30° for the five fields measured), and many of the plates are not of the quality required for such measures.

Boss's *General Catalogue* gives proper motions of stars of the more common spectral types in sufficient numbers to permit good determinations of the motions and mean absolute magnitudes for these types. For types Me, N, R, and S and for variable stars of all classes, on the other hand, the proper motions are not numerous, especially among the brighter stars for which early meridian-circle observations are available. It is desirable therefore that special effort be made to determine the motions of these stars, and since the motions are generally small, they should be determined with the greatest accuracy possible. R. E. Wilson has utilized for this purpose special lists of positions observed in recent years, notably at Lund and at Lyon, and the *Yale Zone Catalogue*, none of which was used in preparing the *General Catalogue*. Proper motions and new positions for 1950 were thus found for 382 stars. With these results, and the data in the *General Catalogue* and others determined photographically, more than 700 proper motions are now available for these special classes of stars.

PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

Work on the magnitudes of stars north of $+80^\circ$, undertaken jointly with Dr. Ross of the Yerkes Observatory, has been continued by Seares and Miss Joyner. The additional series of photovisual plates centered at 85° referred to in last year's report has been completely reduced, and the results have been included in the mean magnitudes. The great majority of the means are of ample precision for use as supplementary standards, but in the lower zones of declination there is still some weakness. With the larger number of stars now available for the determination of plate corrections, it is hoped that some of the long-exposure photographs centered at 83° , which originally gave trouble, can now be included in the reduction.

FAINT PHOTOMETRIC STANDARDS IN SELECTED AREAS

As mentioned in last year's report, the platinum half-filter method has been adopted by Baade for the extension of the photographic scale in a limited number of Selected Areas to magnitude 21. The present half-filter has been carefully investigated with regard to homogeneity and absorption constant. Tests on stars between magnitudes 13 and 17 in a number of Selected Areas show that the adopted photographic absorption constant of the filter conforms with the international photographic scale. Final photographic magni-

tudes to the limit 21 are now available for Area 68. Since the new 3-component zero corrector for the 100-inch telescope is now ready, the work on the remaining Areas should progress rapidly. In addition, the establishment of the photovisual scale down to magnitude 20 has already been started in Area 68.

COLORS OF B- AND A-TYPE STARS

Stebbins and Whitford have completed a survey of photoelectric colors for about 1300 B-type stars, including most of the B0 and B2 stars north of declination -40° and brighter than the limit of the *Draper Catalogue*. The reduction of the observations made at Madison and Mount Wilson to a common system is about finished, and the material is ready for a definitive discussion.

Stebbins and Whitford have also applied a photocell to the spectrophotometry of strongly colored B stars and find that the reddening varies as λ^{-1} , and not as λ^{-4} , as would be the case if the absorption were Rayleigh scattering by small particles in space. From the colors of A0 stars within 10° of the north pole, they find that the obscuration about the pole is due to material more than 100 but less than 250 parsecs distant, causing a mean color excess of about 0.10 magnitude on the international scale.

GLOBULAR CLUSTERS

Christie's program for the measurement of integrated photographic magnitudes of globular clusters reported in 1935-1936 has been extended to include about 80 objects. Except for a few polar comparison photographs that must be obtained at a season when observing conditions are likely to be poor, the observations are complete. Baade's photographs of clusters through red filters, which penetrate much of the obscuring material scattered along the galactic plane, are described on page 201.

SKY PATROL

An experimental monthly patrol, covering as much of the sky as possible, has been finished by Christie. The exposures of 15 minutes, made with a large-field lens of 2 inches aperture, reached the tenth magnitude and were intended for the record of unexpected novæ, comets, etc.

MINIMUM BRIGHTNESS OF WW CYGNI

At the request of Dr. Dugan of the Princeton Observatory, Baade observed the minimum of the eclipsing variable WW Cygni with the 100-inch reflector on J.D. 2428838.73. Dugan's suspicion that at minimum the variable might disappear completely was not confirmed. The minimum photographic magnitude was only 13.9.

STATISTICAL STUDIES

Strömberg has continued his work on theoretical and practical investigations in stellar statistics. The new method reported last year for determination at Washington for publication in their bulletins of *Cosmic Data*. parallaxes, the stars being grouped according to the reduced proper motion H ($H = m + 5 \log \mu$), has been extended and applied to other spectral types for which sufficient data are available. For stars of types G8-K2, and to a less extent for G0-G7 stars, the relation between H and M shows a clear

distinction between supergiants, giants, and dwarfs. The spectroscopic absolute magnitudes have in general been found to require no systematic correction and to have a mean error between 0.5 and 0.6 magnitude. The small dispersion in absolute magnitude among the normal giants of spectral types G8-K2 has been confirmed.

The stars were also grouped according to spectroscopically determined absolute magnitudes, giving a regression line defining the statistical relation between the spectroscopic and the true mean absolute magnitude. Comparison of results derived with this method of grouping with results from the grouping according to H shows that the difference between the "impartial-relation line" and the regression line is not very large for these spectral classes.

The dwarfs of types G0-G7 and G8-K2 have been studied separately. This study shows that the dispersion among the dwarfs has apparently been somewhat underestimated. This effect has been found to be due partly to the use of regression-curves, and partly to errors in the general slope of the reduction-curves.

STELLAR SPECTROSCOPY

Stellar spectroscopic investigations during the year have covered a wide field extending from the study of the brightest stars with high dispersion to observations of supernovæ and other extremely faint stars with low dispersion and cameras of very short focus. The coudé spectrograph in its two principal forms with focal lengths of 9 feet and of 32 inches, respectively, has been used extensively for observations of stars of magnitude 6.5 or brighter. With its aluminized Wood grating, exceptionally bright in the red of the first order and the violet and ultraviolet of the second order, this instrument has been exceedingly valuable for investigations in which high resolving power and good focus over a large extent of spectrum are essential. For studies of the H and K lines and of stars with spectra of early type, the 3-prism spectrograph with the photographic plate centered at about $\lambda 4100$ has been used chiefly. A new camera lens with an aperture of 2 inches and a focal length of 6 inches increases the possibilities of observing faint stars with this instrument, and the spectral types and radial velocities of the fainter stars in the Selected Areas will be determined with its aid. The 1-prism Cassegrain spectrograph has been most useful in observations of faint stars of large proper motion and variables of different types, while the plane-grating spectrograph at the Cassegrain focus of the 100-inch telescope has provided excellent material for the study of the D lines and the yellow and red regions of stellar spectra. For observations of the faintest stars the small spectrograph used for nebular investigations and the 2-prism instrument with collimating mirror and short-focus cameras have been found adequate in nearly all cases.

The stars under investigation have included an extensive list between magnitudes 6.0 and 7.5, selected on the basis of apparent magnitude; a shorter list, selected on the basis of large proper motion, with apparent magnitudes ranging as low as 12.5; probable and possible members of the

Taurus cluster, as selected by Hertzsprung, mainly of magnitudes between 8.0 and 9.5; faint variables; many O- and B-type stars with interstellar calcium and sodium lines; stars in the Selected Areas; and most of the brighter stars which can be photographed with very high dispersion. A total of nearly 1100 spectrograms has been obtained with the seven spectrographs in regular use.

RADIAL VELOCITIES

A catalogue of the radial velocities of 600 stars measured during recent years has been assembled and made ready for publication by O. C. Wilson and Christie. The stars are mainly those of the general observing program with magnitudes between 6 and 8 and spectral types F to M, together with a few fainter stars. The list also includes 69 new spectroscopic binaries. The spectrograms upon which the results are based were obtained through the cooperation of most of the members of the stellar spectroscopic department.

The radial velocities of about 70 stars of early type, with hitherto undetermined velocities, have been published by Merrill and Sanford. The results were obtained in the course of their survey of stars with interstellar lines in their spectra. Five new spectroscopic binaries were discovered in the course of the investigation.

High-dispersion photographs of the spectra of α Boötis, α Lyræ, and γ Cygni, obtained in the second order of the 9-foot coude spectrograph, have been measured by Adams and Miss Lowen for possible variations in the radial velocities of these bright stars. The results so far accumulated indicate that any such variation must be very small, although additional observations are required for α Lyræ and γ Cygni to make the conclusion certain.

A series of 19 observations of α Boötis taken throughout the year has been used by Adams in a preliminary determination of the solar parallax. The study indicates that a relatively small number of observations, made at suitable times and with all possible instrumental precautions, is capable of yielding a value of the parallax quite comparable in accuracy with values derived from extensive astrometric measurements.

The velocities of several spectroscopic binaries and eclipsing stars were observed by Christie, Joy, Karr, and Sanford; among them were β Capricorni, Boss 1074, Boss 3303-4, V Cephei, WW Draconis, W Serpentis, VV Cephei, ζ Aurigæ, and certain late-type binaries with long period.

RADIAL VELOCITIES OF CEPHEID VARIABLES

An extensive spectrographic investigation of the radial velocities of hitherto unobserved variable stars of the δ Cephei type has been published by Joy. Nearly all stars of this type brighter than the fourteenth magnitude and north of declination -40° are included. Velocity-curves are given for 106 variables. For 22 additional stars scattered velocities were obtained from which normal velocities were estimated. The velocity- and light-curves were compared, and the relationships between period, lag of the velocity-curve, range of velocity and light, and form of the curves were studied statistically.

Knowledge of the spectra and the velocities of Cepheids is particularly important from the standpoint of the constitution and internal activities of

stars of high luminosity; and, on account of the great distance of these stars and their concentration near the plane of the galaxy, they are a valuable source of data for investigations of solar motion, galactic rotation, and absorption in space.

ULTRAVIOLET SPECTRA OF EARLY-TYPE STARS

The spectra of several stars of types O and B, photographed with the 32-inch Schmidt camera and grating and the 9-foot quartz spectrograph at the coudé focus of the 100-inch telescope, have been measured by Adams and Dunham in the far ultraviolet region; and, so far as possible, the absorption lines have been identified. In the O-type stars the principal lines between $\lambda 3020$ and $\lambda 3400$ are due to *O* III, *Si* III, *Si* IV, *S* IV, *He* II, and *Ne* II; in the B-type stars, to *O* II, *Si* III, *S* III, *He* I, and *Ne* II. The difference in degree of ionization in the two types is thus well shown by the results. A few prominent unidentified lines were also measured. In the course of the investigation the wave lengths of the interstellar lines between $\lambda 3300$ and $\lambda 4300$ in the spectrum of 55 Cygni were determined.

The spectrum of β Orionis in the far ultraviolet shows great numbers of lines, most of which are due to ionized *Fe*, *Cr*, and *Ti*.

SPECTRA OF GIANT M-TYPE STARS

Reference was made in the last annual report to the discovery by Adams of the double character of a number of lines originating from the ground state of excitation of atoms of neutral and ionized elements in the spectra of α Orionis and α Scorpii. These observations have been continued with the 9-foot grating spectrograph and extended to additional stars. The effect is much more conspicuous in supergiant stars than in ordinary giants and is best illustrated in the spectrum of α Orionis. In this star the *Mn* I triplet near $\lambda 4030$ consists of three pairs of double lines, in each of which the separation is between 0.3 and 0.4 Å. The violet component is much the stronger and is relatively narrow and well defined. The *Cr* I triplet beginning with $\lambda 4254$, the *Sr* II pair $\lambda\lambda 4077$ and 4215 , the *Ba* II pair $\lambda\lambda 4554$ and 4934 , *Ca* I $\lambda 4226$, and a few other lines show similar behavior, although the relative intensities and the separations of the components for the different elements vary considerably.

Measures of the strong violet component and the weaker diffuse red component show that in each case the mean of the two agrees closely with the normal position of the line. This result suggests a reversal effect; but the appearance of the lines, their marked lack of symmetry, and the character of the violet component make this explanation doubtful. It seems more probable that rising and falling masses of gas in the huge atmospheres of these stars may be responsible for the observed displacements, and that the partial analogy with the sharp absorption lines in the spectra of novæ and the displaced emission lines in the spectra of long-period variable stars may be significant. The possibility of ionization effects in the atmospheres of these stars should also be considered. No certain evidence of variation in the structure, the intensities, or the displacements of these double lines in the spectrum of α Orionis has been found during the period of more than a year that the star has been under observation.

Microphotometer tracings of the spectra of some of these M-type stars are being studied by Dr. Spitzer of Princeton University. The results should be valuable because they are not confined to a single object but apparently apply to the physical conditions in a whole class of important stars.

STELLAR SPECTROPHOTOMETRY

The measurement of line contours and intensities in high-dispersion spectra of a selected group of stars has been continued by Dunham. A preliminary study of contours, curves of growth, and ionization in these spectra, based largely on the iron lines, is nearly ready for publication, and a more detailed study of each spectrum is being undertaken with the assistance of Miss Carlson.

The solar spectrophotometer is being rebuilt so as to permit a comparison of different amplifiers. The arrangement is such that light from the same part of the sun as that which is being analyzed is reduced in intensity, by measured amounts, to equality with that in successive narrow sections of the spectrum.

An experimental microphotometer, intended for the study of stellar spectra and embodying many of the same optical and electrical principles, is also under construction. Concave mirrors are to be used in order to eliminate chromatic aberration and give resolution equal to that of the Schmidt cameras used with the stellar spectrographs. Considerable time may be saved in the reductions by recording the photographic densities directly by means of a second concave mirror, which rotates on a transverse axis and scans a logarithmic calibration spectrum until the intensity in the latter equals that at the point in the stellar spectrum which is being measured.

A series of radiometric observations of ϵ Aurigæ has been started by Pettit at the coudé focus of the 100-inch reflector to throw light on the question of color excess. High sensitivity has been obtained with the aid of a thermoelectric relay. The elimination of the accompanying disturbances required much experimental work.

VARIABLE STARS

During the past few years about 130 additional Me and Se variables have been observed by Merrill for radial velocity, making a total of about 280 now observed; but the program is still far from completion. Some progress has been made in the study of typical variables near minimum phase, and material for a general investigation of the bands in the yellow and red is being gathered.

Joy has continued the spectrographic observation of irregular variables without emission lines, of RV Tauri stars, and of short-period variables of the RR Lyræ type. Of the latter group, W Canum Venaticorum has been followed in detail, and a complete velocity-curve is now available. The curve closely resembles the reflected light-curve. The range is 70 km/sec, which points to the possibility of larger velocity ranges for these stars than for the δ Cephei stars. The spectral type varies from A6 to F6.

SU Ursæ Majoris and X Leonis of the U Geminorum class were observed at maximum light. The spectra are practically continuous.

A detailed investigation of the structure of the emission lines of α Ceti has been continued, and several plates were taken at the last maximum with the highest dispersion available at the coudé spectrograph. The relative intensity of the various components of the hydrogen lines was found to change greatly with phase.

Investigation of the changes of line contour and intensity in spectra of the short-period variable RR Lyræ considered in relation to phase has been continued by O. C. Wilson.

NOVÆ

Spectrograms of T Coronæ (1866), Nova (CP) Lacertæ, and Nova Aquilæ (1918) were obtained by Joy. The emission lines of hydrogen and helium in T Coronæ on June 6 and 7, 1938, were stronger relative to the continuous spectrum than in 1921 and were single instead of double.

Observations of the spectra of faint old novæ by Humason have been continued and now include 16 objects which are classified as O Con when the spectrum is continuous with no lines visible, and as O Em when emission is present. In their present state these objects are decidedly blue, and the extension of the continuous spectrum into the violet region corresponds to that of O- or possibly early B-type stars.

Densities of novæ in the final state can be obtained by assuming that the temperature is that of a normal O-type star. The densities of Nova Persei (1901) and Nova Aquilæ (1918), whose distances are reliably known, are of the order of 220 and 70 times the density of the sun, respectively. For a group of 14 other old novæ whose distances are not so certain, a mean density of the order of 60 times the sun has been found. Since the density of normal O-type stars is of the order of 0.1 and that of white dwarfs 10,000 times the solar density, the densities of old novæ seem to be intermediate between these two classes of stars.

INTERSTELLAR MATTER

From measurements of the faint and somewhat uncertain interstellar calcium line $\lambda 4226$ in the spectrum of χ^2 Orionis, combined with a curve of growth derived from interstellar sodium lines, Dunham has determined a value of the ratio of the number of ionized to the number of neutral calcium atoms in space. The result is approximately 2500 singly ionized calcium atoms for each neutral atom. On the basis of this ratio and an estimate of the intensity and spectral distribution of interstellar radiation, it appears that approximately 20 electrons per cubic centimeter are required to maintain the ionization of calcium at the observed level. Calculation then gives the relative numbers of sodium, potassium, calcium, and titanium atoms in each stage of ionization, and finally, the following highly tentative values for the total concentrations in space (per cubic meter): Electrons, 20,000,000. Atoms: Na, 6; K, 0.2; Ca, 0.1; Ti, 0.001.

These values probably represent upper limits and are likely to be materially diminished when it becomes possible to take adequate account of the reduction in the ionizing process which must result from the absorption of a large fraction of the ultraviolet light emitted by distant stars.

The spectra of stars in which $H\epsilon$ does not greatly interfere with interstellar calcium H have been observed by Sanford and O. C. Wilson as a

means of obtaining fairly dependable ratios of the total absorptions of K and H. More than 130 plates were taken. This material permits satisfactory evaluation of the total-absorption ratio except in the case of unusually weak or strong interstellar lines, for which further observations are needed.

Merrill and Sanford have found that the ratio of intensity of D2 of sodium to K of calcium, derived by direct comparison in spectra where both lines were measured and also from the distance-intensity curves of the two lines, is 1.6, with little evidence of any change in the ratio with intensity. This value probably indicates about three times as many atoms of singly ionized calcium as of neutral sodium.

High dispersion at the coudé focus of the 100-inch telescope has been used by Sanford for a detailed study of complex interstellar lines. In addition to the stars in which such lines have previously been reported, those shown in the accompanying table have been found to have double interstellar cal-

HD No.	Ca II displacements		Total absorption	
	Violet comp.	Red comp.	Violet comp.	Red comp.
	km/sec	km/sec	Angstroms	Angstroms
829	-42	-13	.....	.....
37022	+ 6	+27	.....	.....
93521	-59	-12	0.07	0.11
190429 N	-76	-12	0.10	0.41
190429 S	-80	- 9	0.07	0.38

cium lines. The second and fourth were found by O. C. Wilson. The velocities for HD 37022 (θ^1 Orionis C) accord with the means (+1.1 and +25.9 km/sec) of the Mount Wilson measures of the previously known double interstellar lines in 5 Orion stars. The agreement and constancy of the displacements for the N and S components of HD 190429, both of which are spectroscopic binaries, is excellent proof of the interstellar nature of the lines. Within the errors of measurement their total absorptions seem to be the same.

The radial velocity of HD 8065, type cA2, was found to be large enough, -76 km/sec, to separate the stellar H and K lines clearly from the interstellar lines, whose velocity is -8 km/sec.

Two additional lines, $\lambda\lambda 6203.0$ and 6263.0 , observed by Merrill and O. C. Wilson should probably be added to the previously reported groups of unidentified interstellar lines in the yellow and red. Moreover, it now appears that the wide, diffuse feature at $\lambda 4430$, suspected for several years of being detached, actually has an interstellar origin. Strong statistical evidence in favor of this hypothesis was adduced by Beals and Blanchet at Victoria, and confirmation is found in a recent investigation by Merrill and Humason which shows the line to be stationary, within the errors of measurement, in the spectroscopic binary HD 163181.

Recent trials by Merrill and William Miller show that interstellar D lines are readily observable in spectra photographed with the 10-inch re-

fractor and the 15° objective prism. These lines offer the advantage that the corresponding stellar lines interfere but little in types earlier than A3, while with interstellar K interference becomes serious at B5. A preliminary list of early-type stars examined on the objective-prism plates includes a considerable number of the seventh and eighth apparent magnitudes whose detached D lines are more intense than normal stellar D lines in type G. Most of those of types B8 to A2 will probably prove to be c stars. When the new photovisual refractor becomes available, this program will be combined with one for the detection and reobservation of stars with bright $H\alpha$.

GALACTIC ROTATION

The normal radial velocities of the Cepheid variables have been used by Joy to study the rotation of the galaxy. These stars are particularly suited to the purpose on account of their distance, spectra, and concentration near the plane of the galaxy. Photometric distances based on the period-luminosity relation were found to be largely affected by space absorption, for which a correction of 0.85 magnitudes (photographic) per 1000 parsecs was applied. The results indicate that the rotation plays an important part in determining the apparent motions of these stars. Estimates of the galactic constants, based on a high concentration of mass at the center, give: solar orbital velocity, 296 km/sec; longitude of direction to center of rotation, 326°3; and radius of sun's orbit, 10,000 parsecs. The lack of observations of southern stars which cannot be reached from Mount Wilson greatly decreases the weight of the solutions.

A study of the motions of interstellar gas based on all available measurements of detached lines was made by Merrill and Sanford. Curves for various distances from 150 to 1200 parsecs approximate fairly closely to the expected double sine curves characteristic of galactic rotation of the "planetary" type. Altogether the data strongly support the conclusion of Plaskett and Pearce that interstellar matter takes part with the stars in galactic rotation. A distortion in the curves for the nearer material in longitudes 125°–164° may perhaps have some connection with the stream motion of the Taurus group. A least-squares solution yields for the constants of galactic rotation

$$l_0 = 329^\circ, \quad A = 14.8 \text{ km/sec per 1000 parsecs.}$$

The nearer gases give a somewhat larger value of the constant A than those at greater distances. Obscuration seems inadequate to account for this result, which may possibly be due in part to a decrease in the average density of interstellar gas beyond about 1000 parsecs from the sun.

MISCELLANEOUS

Observations of stars with peculiar spectra have been continued by Merrill, and several spectra of classes R and N have been photographed by Sanford with the coude plane-grating spectrograph.

The intensities of lines of ionized barium in early-type spectra have been studied by Miss Burwell.

Considerable progress on the program of faint stars of large proper motion and low luminosity has been made by Adams, Humason, and Joy. A list of

25 stars for which unpublished radial velocities were in excess of 75 km/sec was prepared. Most of the highest velocities, eight of which are greater than 150 km/sec, are given by F-type stars with large proper motions.

Observations of stars in the Selected Areas have been continued by Strömberg. Thus far three or more spectrograms have been taken for 221 stars, two for 48 stars, and one for 69 stars, leaving 92 stars of the list still unobserved.

Several spectrograms of the white dwarf AC +70°8247 were obtained by Minkowski. Although the spectrum has been reported as continuous, microphotometer tracings of widened spectra show the presence of at least two extremely wide, shallow absorption regions at about $\lambda\lambda 4135$ and 4475 . Unique identification has not been successful; a search for further absorption, especially in the red part of the spectrum, has therefore been started.

Among the faint stars observed by Humason were several in the region of the Orion Nebula and an A-type star of seventeenth magnitude found by Baade in the field of the old nova B Cassiopeiæ. On the assumption that the absolute magnitude of the A star is roughly +1.0, the distance modulus, uncorrected for space absorption, is 16.0, which indicates a distance of 25,000 parsecs in a direction 125° from the galactic center.

In connection with their study of interstellar lines in spectra of early type, Merrill and Sanford have revised the absolute magnitudes for the various spectral subdivisions adopted on the basis of the distance-intensity relationships previously used. The results show: (a) that differences in absolute magnitude between stars with diffuse lines and those whose lines are better defined are smaller than those originally found; (b) that there is a smaller decrease from O9 to B8; (c) that c stars of classes B3 to B9 are fainter than the assumed mean value -5.0 , while those of classes A0 to A2 are brighter; and (d) that the mean magnitude of a few Wolf-Rayet stars is -2.9 .

In spectrograms of θ^1 C and θ^2 Orionis and other stars embedded in the Orion Nebula, taken with the 3-prism violet spectrograph, a sharp absorption line of considerable strength has been found by O. C. Wilson at $\lambda 3888$. This line also appears on spectrograms of θ^1 C Orionis taken by Dunham with the Schmidt-camera spectrograph at the coudé focus. The line is superposed on the broad diffuse $H\zeta$ absorption characteristic of the stars. As there is no known interstellar line in this position, it may be attributed to the transition $2^3S-3^3P^\circ$ in the helium atoms of the nebula. The measures obtained seem to indicate a systematic velocity of approach for $\lambda 3888$ as compared with the emission-line velocities of the nebula. Presumably this velocity difference is a result of the pressure of radiation from the stars acting upon the helium atoms in the nebula. The intensities of the line in the spectra of the various stars do not show a correlation with their reddening as measured by Baade and Minkowski. The line has been looked for without success in stars associated with Messier 8 and 20 and in spectra of the nuclei of two planetaries.

In a study by O. C. Wilson of the structure of H and K of calcium in the spectra of late-type stars, a bright line was found within the wing of H in the spectrum of α Boötis. Measures of position tentatively identify the line as emission from hydrogen H_ϵ .

GALACTIC NEBULÆ

RED PHOTOGRAPHY OF NEBULÆ AND CLUSTERS

Baade has continued his program of direct photography through red filters, giving special attention to the region of the galactic center. The investigation is of exceptional importance because it has partially penetrated the heavy obscuration that hides the nucleus of our system. A survey in duplicate (red and blue) of the region galactic longitudes 300° to 350° , latitudes $+8^{\circ}$ to -8° , made with the 18-inch Schmidt reflector on Mount Palomar, fully confirms the strong selective absorption reported a year ago. The greater space penetration of the red films, relative to the blue, introduces marked differences in the pattern of obscuring clouds. Further, various faint extended nebulosities, absent or inconspicuous in the blue survey, are well recorded in the red, presumably by strong *H α* emission. For instance, NGC 6357, of which only one or two small wisps appear in the blue, is an outstanding object on the red films, rivaling in size the Orion Nebula and Messier 8. Among a number of new clusters found during the survey, subsequent checks with the large reflectors disclosed half a dozen very heavily obscured globular clusters.

Other objects photographed in the red include the Crab Nebula, the North America Nebula, various nebulosities in the Taurus obscuration, a new emission nebula at R.A. $23^{\text{h}} 49^{\text{m}} 8$, Dec. $+60^{\circ} 8'$ (1937), and several extragalactic nebulae and clusters.

One difficulty encountered in the work is the variable, and sometimes heavy, sky fog appearing on the red films after only moderate exposures. Since the fog on a given night is a function of zenith distance, its source must be atmospheric—probably the red auroral lines. It seems possible that the occasional difficulties encountered during the past half-year may have been due largely to the high frequency of sunspots, now near maximum. To test this point a spectroscopic investigation is now under way.

A REMARKABLE CHANGE IN THE VARIABLE NEBULA NGC 2261

On photographs taken by Baade at the end of December 1937, the preceding half of the variable nebula NGC 2261 appeared with its usual intensity, while the following half was completely obscured. Since the boundary of the illuminated area was a sharp, straight line, passing approximately through the exciting star, R Monocerotis, it seems evident that an obstruction near the star threw a shadow on the following half of the nebula. Poor weather permitted only a meager record of the phenomenon, but a few photographs were obtained in January and February 1938. During this interval, the edge of the "shadow" moved from west to east at the rate of $0'.08$ per day, but lost its straight-line appearance and became slightly ragged.

PLANETARY NEBULÆ

Duncan has continued his program of long exposures on planetary nebulae, fifteen of which were studied. No new envelopes similar to those found for the Ring Nebula in Lyra and NGC 6826 were discovered, but interesting details not previously published were found in NGC 6210 and 6751 and in IC 3568 and 4634.

INTERFERENCE SPECTROGRAMS OF GALACTIC NEBULÆ

From interference spectrograms of the planetary nebula NGC 6826, Minkowski has found a rather complicated distribution of radial velocities such as might be expected from a rotation of the nebula around its minor axis, with velocities decreasing from the equator toward the poles.

Minkowski has also obtained numerous interference spectrograms of Messier 8 and of the Orion Nebula, preparatory to a detailed study of the radial velocities in these large diffuse nebulae.

EXTRAGALACTIC NEBULÆ

The major development during the past year has been the cooperative study of two supernovæ in extragalactic nebulae, in a manner more detailed and comprehensive than has hitherto been possible. Supernovæ represent the sudden release of energy on a scale which far transcends that of any other known phenomenon (one of the two recent supernovæ reached a maximum luminosity of the order of 10^9 suns). For the first time, sufficient information has been assembled to investigate, rather than to speculate upon, the behavior of matter and radiation under the extreme conditions represented by the explosions.

In the general field of extragalactic research, emphasis has been shifted from the study of the observable region as a sample of the universe, to the detailed investigation of nebulae as stellar systems. The problems of nebular structure and evolution have replaced, for the time being, the problem of cosmology.

MOUNT WILSON COLLECTION OF PHOTOGRAPHS OF NEBULÆ

During the year an extensive observing program was finished by Hubble which was undertaken for the purpose of obtaining good photographs with the large reflectors of the 800 nebulae in the Shapley-Ames catalogue, north of declination minus 30° and equal to or brighter than the limit of completeness at photographic magnitude 12.9. The task of enlarging the Mount Wilson collection of photographs to meet these specifications has required the cooperation of several observers over a period of years. In the course of this and other more special programs, photographs of many fainter nebulae have also been assembled until the collection now includes about 2000 NGC objects and nearly 1000 given in the IC.

Since the material is complete for the brighter nebulae (over three-quarters of the sky) and probably representative for the fainter objects, attention has now been diverted from the compilation to the analysis of the data. The investigations include detailed, quantitative studies of the sequence of classification, of the relative frequencies of various types, and of the small-scale distribution of nebulae.

SHORT-PERIOD CEPHEIDS IN MEMBERS OF THE LOCAL GROUP

Another cooperative observing program has been carried out by Hubble, Baade, and Humason for the study of short-period Cepheids in the four neighboring nebulae, M 31, M 33, NGC 6822, and IC 1613. Long exposures with the 100-inch reflector were made for each nebula on 10 to 12 successive nights. Some 60 new Cepheids have been identified. An investigation of

the variables in IC 1613 by Baade is practically complete. The magnitudes are on the scale for very faint stars which he established in Selected Area No. 68. This scale is now being transferred to the three additional nebulae.

SPECTROGRAPHIC INVESTIGATIONS OF EXTRAGALACTIC NEBULÆ

Humason has determined apparent velocities and spectral types of 21 extragalactic nebulae. The list includes members of clusters and groups of nebulae, and several large, resolved, and hence near-by nebulae, some of which exhibit small negative velocities. He has also obtained a spectrogram of the bright, central region of NGC 4111, with a dispersion about double that previously used in the study of the rotation of this object. The new spectrogram extends out 20" from the nucleus along the major axis. Since the exposure time was not impracticably long, the larger dispersion will be used for a more precise reinvestigation of the rotations of NGC 4111 and 3115.

SUPERNOVÆ

In the autumn of 1937 Dr. Fritz Zwicky, of the California Institute of Technology, discovered two supernovæ in the nebulae IC 4182 and NGC 1003. The observed maxima, apparent magnitudes 8.6 and 12.8, respectively, were the brightest recorded since 1895 (Z Centauri), and the nebulae themselves were well placed for observation at the latitude of Mount Wilson. The remarkable phenomena could therefore be studied in detail with the large reflectors, and for the first time it was possible to use spectrographs with adequate dispersions. The fortunate chance that two of these mysterious objects could be studied simultaneously has added materially to the significance of the results. The investigations at Mount Wilson were carried on principally by Baade (photometry), and by Minkowski and Humason (spectrography), working in close cooperation with Zwicky, who used the 18-inch Schmidt reflector on Mount Palomar.

Baade established sequences of photographic magnitudes and constructed definitive light-curves covering the first observing season, and obtained the data necessary to derive similar results based on red magnitudes. The supernova in NGC 1003 was discovered before maximum and that in IC 4182 probably a few days after maximum. The two light-curves are similar and follow the normal pattern. It is believed that it will be possible to observe both stars for at least a portion of the next season.

The two nebulae are resolved, late-type spirals. From their brightest stars, Baade has estimated distances of 0.9×10^6 and 1.5×10^6 parsecs for IC 4182 and NGC 1003, respectively. Humason has found +475 km/sec for the apparent radial velocity of NGC 1003, consistent with the estimated distance, within the uncertainties introduced by accidental errors and possible peculiar motion. The corresponding photographic absolute magnitudes of the supernovæ are -16.6 and -13.2, the former (for that in IC 4182) being the brightest that has been reliably determined.

SPECTRA OF SUPERNOVÆ

Minkowski, using dispersions of 75 and 150 Å per mm at $H\gamma$, and Humason, using a dispersion of about 400 Å, have obtained (1) a series of 30 spectra of the supernova in IC 4182, beginning August 29, 1937 (presumably about

nine days after maximum), and still in progress, and (2) a series of 10 spectra of the supernova in NGC 1003, beginning September 11, 1937 (about two days before maximum), and extending to January 6, 1938. Minkowski is now analyzing this extensive collection of data.

Except for minor differences, the two series of spectrograms are closely comparable at corresponding times after maxima and are consistent with the fragmentary records of previous supernovæ. The data indicate clearly that the spectra of supernovæ form a distinct class, entirely different from the spectrum of any other known object (including ordinary novæ).

The recorded spectra, which extend from $\lambda 6800$ to $\lambda 3700$, apparently consist of wide, partially overlapping emission bands. The blue region ($\lambda < 5000$) is dominated by a strong band in the neighborhood of $\lambda 4600$ but also contains several fainter bands. After some variations in relative intensities during the first three weeks, a fairly stable pattern developed, which persisted with only minor changes throughout the remaining period of observation. However, the pattern as a whole shifted gradually toward the red, the total displacement amounting to about 100 Å by June 1938 for the supernova in IC 4182, and to about 70 Å by January 1938 for that in NGC 1003.

The behavior of bands in the red ($\lambda > 5000$) was conspicuously different from that of bands in the blue. The red bands varied rapidly, appearing and disappearing in a manner somewhat resembling that of emission bands in ordinary novæ. Eventually, in February 1938 (after NGC 1003 was out of reach), two narrow bands, each about 40 Å wide, appeared at $\lambda 6359$ and $\lambda 6299$ in the spectrum of the supernova in IC 4182. The stronger band, at $\lambda 6299$, was still conspicuous in June 1938, when all the other bands in the red had almost completely disappeared. Because of the rapid variations, the red shift easily observed in the blue could not be investigated with confidence in the red region of the spectra.

Until the red shift can be interpreted, the identification of details in the spectra presents a very difficult problem. At the moment, the only plausible identification is that suggested by the close coincidence of the two narrow red bands with the forbidden oxygen lines at $\lambda 6364$ and $\lambda 6300$. No features have been observed which could possibly be attributed to hydrogen.

The narrowest details shown in the early spectrograms suggest widths for individual bands of the order of 100 Å. While it is not impossible that individual bands may have had different widths, the data thus suggest that, on the assumption of expanding shells, the velocities at most were not greater than 3000 km/sec.

LABORATORY INVESTIGATIONS

SPECTRUM OF EUROPIUM

Data for the spectrum of europium, collected at intervals for some time past, have been put in final form by King. These data include wavelength measurements for approximately 3750 lines between $\lambda 2100$ and $\lambda 10165$, nearly three times the number previously known; the segregation of the lines of neutral and singly ionized atoms by a comparison of arc and spark

spectra; and the temperature classification of both neutral and ionized lines by means of furnace spectrograms made at different temperatures. The hyperfine structure of most of the europium lines and the great range in their intensities caused unusual difficulty in obtaining both wave-length measurements and intensity estimates. The number of plates required to do justice to the various types of lines is much larger than for any rare earth previously studied. The collection has been supplemented during the year by spectrograms made with pure europium oxide contributed by Dr. H. N. McCoy, which are free from the disturbing band structure present on the earlier spectrograms. Absorption furnace spectra for the region of shorter wave lengths, where the emission spectrum is weak, were used to detect faint lines arising from low atomic levels.

Lines in the solar spectrum belonging to the rare earths are very faint. With the exception of two neutral lines of ytterbium, those previously identified are due to the ionized atom. A search for europium lines made with the aid of the improved wave lengths and the temperature classification revealed over twenty neutral lines, all very strong in laboratory spectra, agreeing closely with faint, unidentified solar lines. As would be expected, the lowest-temperature (ultimate) lines are found in sunspot spectra, while those requiring higher laboratory temperatures appear in the solar disk. In the *Revised Rowland* five solar lines were identified with singly ionized europium. Use of the new laboratory data has increased this number to twenty-seven.

SPECTRUM OF GADOLINIUM

King has begun an investigation of the spectrum of gadolinium with the aid of a very pure preparation of the element supplied by Dr. McCoy. About 60 photographs of furnace, arc, and spark spectra have been made, and preliminary examination shows a very definite temperature grouping of the lines. The lines easily measurable will greatly increase the number now known.

For comparison with celestial spectra King has photographed the rich band spectrum given by sodium vapor in the region $\lambda 4500\text{--}\lambda 6700$. These bands appear in absorption on furnace spectrograms made at low temperatures.

VACUUM SPARK

The large glass-plate condenser constructed in 1925 has now been replaced by two commercial units, each of one-half microfarad capacity and 50,000 volts. These condensers perform fully as well as the large condenser, and since they require only two square feet of floor space instead of the forty or more occupied by the old unit, the change has been of great advantage in a laboratory as crowded as ours.

During the year Anderson has photographed the vacuum spark spectra of a number of elements in the visual region $\lambda 4500\text{--}7000$. The exposures required are enormously longer than in the region of shorter wave lengths. Whereas 5 to 10 sparks suffice for most elements in the region $\lambda 2200\text{--}4500$, 200 to 400 sparks are required to photograph the red part of the spectrum satisfactorily. With these longer exposures the spark terminals not only

wear away considerably, but also are deformed into shapes very awkward for the proper illumination of the spectrograph. By varying the initial shape and size of the terminals it is possible to control the deformation to some degree. Unfortunately, however, different elements behave differently, so that thus far only a beginning has been made in overcoming the difficulty, which, of course, must be overcome completely before this source can become generally useful for laboratory purposes.

RULING MACHINES

About a year ago Babcock found that the screw of the new ruling machine was undergoing spontaneous changes in form so large that it must be replaced. After consultation with theoretical and practical experts on steel, followed by exacting tests in our own shop, construction of a new screw was begun. The cutting of the thread was completed in March and the various nuts for lapping and using the screw are now being made.

The special shop formerly a part of the ruling-machine laboratory has been restored and improved by the addition of valuable equipment no longer needed at the Hale Solar Laboratory.

Several small gratings have been ruled on the old machine, chiefly to study the distribution of brightness in their spectra. Both visual and photoelectric methods of measurement have been used and their results are in good agreement. It has long been known that the intrinsic brightness of a given order of spectrum often depends on the angle of incidence. Measurements show that in some cases the variation may be more than twofold. It is not yet controllable at the time of ruling and calls for further investigation.

With the aid of a photronic cell, Babcock has compared the luminous efficiency of several of our gratings with that of excellent gratings ruled elsewhere. The most interesting result appeared for two gratings, each with high concentration in one second-order spectrum. The Mount Wilson grating, although ruled on speculum and subsequently aluminized, is brighter than the other, ruled on evaporated aluminium deposited on pyrex, in the ratio 9:8. The comparison was for $\lambda 5461$ and was made with each grating at its most favorable angle of incidence. Nevertheless, it seems probable that evaporated aluminium ruled directly can be made to return more light than aluminium superposed on a ruling already made. Under the most favorable conditions gratings can now be ruled which return from 50 to 60 per cent of the incident, visible, monochromatic radiation in one order. Various related details of technique are under investigation, several of which now await trial rulings.

AUDITORIUM AND EXHIBIT HALL

The new auditorium and exhibit hall on Mount Wilson have continued to serve their purpose admirably. The exhibit of astronomical photographs, shown as transparencies, is open to the public on Friday evenings and for an hour each afternoon. The dome of the 100-inch telescope is also opened each afternoon and the mechanism and operation of the instrument are explained to visitors. Friday evenings an illustrated lecture is given in the auditorium

preceding the demonstration at the 60-inch telescope, to which visitors are admitted on these evenings. During the summer months, when the crowds are large, visitors who cannot gain admission to the lecture hall go at once to the 60-inch telescope. Hickox and Christie have given the evening lectures and usually have served as curators in the exhibit hall when it was open in the afternoon. During the year, 11,191 visitors were admitted to the 60-inch telescope for the Friday evening demonstration—1000 more than for the preceding year, in spite of the fact that for three months Mount Wilson was inaccessible to the public because of storm damage to the Angeles Crest Highway.

CONSTRUCTION AND MAINTENANCE

60-FOOT TOWER TELESCOPE

After many years of constant use the 60-foot tower telescope is in process of reconstruction. The remodeled instrument will include various features of convenience suggested by past experience and many others made possible by modern developments in science and industry. To prevent the shadow of the dome falling on the cœlost at certain hours, the dome and its supporting tower will be moved about four feet north relative to the second tower, which carries the optical parts. The new cœlost, provided with a 22.5-inch mirror, will be controlled by a special synchronous motor through a drive designed by Nichols, which will permit the observer to change the rate without ascending the tower. An automatic guiding device, operated by a photoelectric cell and a thyratron tube, will be a part of the new drive. This device, recently developed by Whitford, is already in use, and in practice has proved very effective. The second flat will be mounted on a polar axis and otherwise will more nearly resemble that of the 150-foot tower. The designs incorporate several other features of importance, and later it is planned to include a new spectrohelioscope and a temperature-controlled dark room. The shop work on the new instrument is well advanced and by the first of the year it should be possible to make the transfer from the old instrument to the new.

ENGINEERING DESIGN

In the engineering department E. C. Nichols, assisted by H. S. Kinney, has completed designs and drawings for the reconstruction of the 60-foot tower telescope and for numerous special pieces of apparatus, among them a spectrograph for use at the primary focus of the 100-inch telescope; a 21-foot Eagle-type concave-grating spectrograph for the Solar Laboratory; new prisms and mountings for Cassegrain spectrographs IX and XI; a 6-inch camera and a truck for spectrograph XII; two microphotometers and a microphotometer amplifier; a 9-inch cœlost and second flat to be used in forming a solar image at the exhibit hall; a spectroheliokinematograph; and a stereocomparator for the examination of plates up to 8×10 inches.

Preliminary studies and sketches have also been made for several projects, including a remote control for rating the driving clock, and a declination drive and lunar guider for the 100-inch telescope; a 10-inch photovisual refracting telescope; and a 24-inch Schmidt telescope with mounting and

dome. A large amount of time has also been given to the preparation of illustrative material for the Observatory publications and for the annual exhibit of the Carnegie Institution.

INSTRUMENT AND OPTICAL SHOPS

Alden F. Ayers, for more than thirty years a most efficient foreman of the machine and instrument shop, retired on August 1, 1937. To his deep regret, serious illness during several months prevented him from rounding out his full term of service. He has been succeeded by Albert McIntire as foreman. Owing to the reconstruction of the 60-foot tower telescope, the shop activity during the year has been greater than usual. The new construction includes all the apparatus listed in the preceding section and many miscellaneous items such as work on the ruling machines, a mounting for zero corrector No. 2 for the 100-inch telescope, the butane installation for Mount Wilson, and much repair and maintenance work.

The optical work has been carried on by John S. Dalton with the assistance of D. O. Hendrix. Much work has been done on Schmidt cameras, including three with focal ratios of 0.66, 1.0, and 1.0, and foci of 2, 3, and 9 inches, respectively. Other Schmidt mirrors of 17, 20, 26, and 30 inches were also finished. A 36-inch grinding machine was built to care for this work. A precision edger was also developed and built. The 7.5-inch, three-lens zero corrector for the 100-inch telescope has been completed. Other work includes the optical parts for two solar-spectrum photoelectric amplifiers and for spectrograph 6B, two L2 prisms for spectrographs IX and XI, guiding eyepieces, step wedges for photometry, and many small mirrors, lenses, prisms, and filters.

BUILDINGS AND GROUNDS

The usual maintenance of the buildings in Pasadena and on Mount Wilson has been carried on by A. N. Beebe, Superintendent of Construction, the largest single item being the painting of the 150-foot tower telescope. The paving of the road on the Observatory grounds begun last year to control the dust has been extended around the 60-inch telescope and from there halfway to the 100-inch dome. The result has been most satisfactory. The damage to Observatory property by the severe rainstorm beginning in the last days of February (see p. 184) was negligible. A butane heating system has been installed in the kitchen range and in several of the rooms of the Monastery.

Sidney Jones, Engineer, and Kenneth de Huff, Assistant Engineer, as usual, have maintained the mechanical and electrical equipment of the buildings and instruments on Mount Wilson.

THE LIBRARY

During the past year 393 volumes, 25 by gift, 43 by purchase, and 325 by binding, have been added to the library; the total number is now 13,743, with over 10,000 pamphlets. The number of serial publications received regularly in 1938 is 140; of these, 39 are gifts and exchanges, as are also the publications, appearing at irregular intervals, of more than 200 observatories and research institutions.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

In 1922 an extensive series of investigations was inaugurated, under the support of the Carnegie Institution of Washington, to determine the manner in which climatic influences are expressed in modification of plants, and the manner in which they are differentiated to meet the complex demands of various environments. These investigations, which have come to be known as transplant or varied-environment experiments, have been carried out at a number of stations ranging in altitude from sea level to the crest of the Sierra Nevada. The extensive mass of observational and statistical data has been collated during the past few years, and the results assembled for publication. The completion of this work marks a definite node in one of the most extended investigations which have been carried out in the Division.

Two investigations dealing with the chemistry of the photosynthetic apparatus of plants have been brought to publication. The first of these concerns the leaf xanthophylls, a group of yellow pigments contained in all chloroplasts. Because of the fact that these substances possess a very complicated chemical structure and because the various members of the group differ only very slightly in structure and in their chemical properties, their isolation and purification have been associated with many difficulties. The isolation of these extraordinarily sensitive compounds was made possible largely through the development of special methods of chromatographic adsorption. By this means and through the accurate determination of the absorption spectra reliable methods have been evolved for the characterization of this important group of naturally occurring substances. The other investigation referred to concerns the mechanism by which the plant leaf absorbs the carbon dioxide of the atmosphere. This is the first step in the series of chemical reactions comprising photosynthesis. The more exact determination of the chemical system which is involved in this first step has served to establish another link in the series of chemical reactions comprising the photosynthetic process.

Photosynthesis in plants is essentially an energy-storing chemical reaction. This energy is obtained from the light which is absorbed by the pigments in the leaves of the plant, and is used in reducing carbon dioxide to a carbohydrate. The amount of energy which is required by the plant to carry forward this chemical reaction is of fundamental importance in establishing the chemical mechanism which is involved in the process. During the past year a reinvestigation of the quantum efficiency of photosynthesis has been begun by Drs. Robert Emerson and Charlton M. Lewis, with a view to making certain essential amplifications of previous determinations with improved apparatus, and with special consideration of the physiological characteristics of the plant organisms used.

The recent publication of the results of thirty years' observation of changes in vegetation on the fenced lands of the Desert Laboratory has attracted the interest of both foreign and American workers who are dealing with the

¹The Central Laboratory of the Division is located at Stanford University, California.

problems of restoration and maintenance of grazing ranges. Shorter periods of observation of the reproduction and growth of large desert perennials have emphasized the slowness of growth of individual plants and the long periods required to bring about change in the communities which they form.

The close of active field work on the Sonoran Desert project, which has been one of the principal activities of the Desert Laboratory for the past five years, has been followed by study of notes and collections preparatory to publication. The work of the past year has been almost as fruitful as the years of exploration, since it has given time for the study of living and herbarium material and the collation of data on climate, vegetation, and the distribution of some of the most highly specialized desert plants. The objective of these investigations has been the determination of the origin of desert plants and their differentiation under the impact of the severe environmental conditions of the arid regions.

A publication of the Institution written by Ralph W. Chaney in collaboration with Dr. Hsen Hsu Hu, Director of the Fan Memorial Institute of Biology, describes a fossil flora from Shantung Province, China. This represents the first record in China of the Miocene vegetation so common in western North America. In spite of significant differences, the forests on opposite sides of the Pacific contained many of the same trees. This supports the suggestion that there was a migration route between North America and Asia during the Miocene, probably across the Bering Sea region.

BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, AND H. W. MILNER

LEAF PIGMENTS

Carotenes. Reexamination of the carotenes of carrot roots has demonstrated the presence of relatively large quantities of a pigment having spectral absorption properties similar to those of the flavoxanthins, a group of rare xanthophylls. This pigment is readily isolated by adsorption upon magnesia columns. It exhibits unusually strong absorption of light at short wave lengths. Consequently, it may be detected in the presence of considerable quantities of alpha- and beta-carotene by determination of the spectral absorption properties of the mixture.

Leaves of several species of plants which are known to contain various proportions of alpha- and beta-carotene (sunflower, tobacco, carrots, and incense cedar) were found, by spectroscopic analysis of the pigments, to contain little if any of the flavoxanthin-like carotene. Since carrot roots and incense cedar are relatively very rich sources of alpha-carotene and only the former contains much of the flavoxanthin-like pigment, it may be concluded that the occurrence of the flavoxanthin-like pigment in natural products is not directly related to the alpha-carotene content.

In order to confirm identification of the carotenes of butter reported from this laboratory, comparative studies of the spectral absorption and chromatographic adsorption methods have been made. Chromatographic adsorption has been found to be the most sensitive and specific method for the

identification of alpha-carotene and the flavoxanthin-like carotene in mixtures of these with beta-carotene. Application of these methods to an investigation of the carotenes of butter from Jersey cows has shown that the carotenes of the butter are dependent upon the carotenes contained in the rations of the animals. Addition of alpha-carotene and of the flavoxanthin-like carotene to the rations of cows, which had previously received food containing principally beta-carotene, resulted in the transference of all these substances to the butter fat. These investigations, which were made possible through the cooperation of Dr. H. R. Guilbert, of the University of California at Davis, have demonstrated the wide applicability of the analytical methods originally developed for the analysis of leaf pigments.

All green leaves examined thus far have been found to contain colorless, fluorescent substances, which, from their behavior upon adsorption columns, appear to be related to the carotenoids. Chemical investigation of these interesting compounds has been hampered by the great difficulties encountered in the isolation of the pure compounds. It has now been found that these fluorescent materials occur in relatively very large amounts in carrot roots, from which they are readily isolated by adsorption upon magnesia columns. This discovery, by providing a supply of raw material, may make possible a thorough chemical examination of these fluorescent components of leaves.

Some absorption spectra of leaf extracts and their significance. It has previously been found that certain xanthophylls are readily destroyed by oxidation when ordinary methods of extracting leaf pigments are used. This led to some uncertainty as to the fate of chlorophyll under similar circumstances, because various methods of killing leaves may cause striking differences in appearance of the killed material. For example, with anæsthetics, tolucized leaves dried in air lose their bright green color, and become brownish, whereas when dried in hydrogen, they retain it. A sunflower leaf when dipped in boiling water loses, *inter alia*, its intercellular gases and becomes more opaque, but is still deep green in color. Sorrel on the other hand immediately turns brown.

The significance of such changes has now been studied by Dr. G. MacKinney in two ways: first, by an examination of the absorption spectra of suitably prepared extracts, and secondly, by application of the Tswett column technique. The changes observed in the absorption spectra could be classified into four groups:

1. Conversion of chlorophyll to pheophytin. This occurs most readily in leaves of acid sap, such as sorrel.

2. Hydrolysis of the chlorophyll. Apparently of rare occurrence, it was noted in certain sunflower extracts, and is presumably related to the alkalinity of the sap. In this respect sunflower leaves would appear to be similar to those of sugar beet, where it is known that the carbon dioxide exerts a marked effect on the pH of the sap, which may become definitely alkaline.

3. Oxidation of the chlorophyll. This may be easily regulated in small-scale operations, where 5 to 10 grams of leaf material are used. Where, however, a kilogram or more is taken, for the isolation of pure chlorophyll, it may develop to serious proportions. If in fact there are but two chlorophyll components, then it may be to oxidative changes that the supposed third com-

ponent owes its origin. There can be no chance of mistaking the other types of change liable to occur where laboratory extraction procedure may be at fault.

4. Changes in the ratio of chlorophylls *a* and *b*. Where methods appeared satisfactory for a given species of plant, with no detectable degradation, it became necessary to investigate the fixity of the ratio of the two known components, which were separated on Tswett columns composed of inulin. The problem was attacked indirectly, by showing that for seven species of plants examined, there were only two components, blue and green, corresponding to chlorophylls *a* and *b*, respectively. Preparations of the blue component were found to be spectroscopically identical regardless of the source, and the same was true for preparations of the green component.

Traces of degradation products may therefore yield erroneous results, where dependence is placed exclusively on spectroscopic analysis. The greatest danger arises with plants of acid sap. Anæsthetics, by modifying phase relationships, exposing previously protected pigments to air, may have an equally serious effect on plants whose sap is nearer neutrality. They should therefore be used only in the presence of an inert gas. The ratio of chlorophylls *a* to *b* apparently fluctuates within rather narrow limits regardless of age of tissue or time of day. These observations of course apply only to healthy plants grown under field conditions. Substantial differences, however, are recorded for different species of plants. Adsorption studies with inulin do not favor the hypothesis of a third component of chlorophyll. The rapidity with which the individual components may be obtained, insuring a minimum of change, has been of great value in evaluating the usefulness of a method for a particular species of plant. Of the five general methods employed, drying, direct solvent extraction, freezing, dipping in boiling water, and anæsthetics, the first two are the most generally applicable. Drying at room temperature *in vacuo* was particularly satisfactory for the acid sorrel, but could not be applied readily to tobacco. It is obvious, when one considers the diversity of leaf structures, that no one method can be invariably applicable, and it becomes important that a method should be critically examined for possible flaws when used on a particular plant.

Chloroplasts. The studies on silver nitrate reduction by chloroplasts, carried out by Dr. Elliot Weier, have been brought to a conclusion and published. They corroborated the suggestion of the French worker, Giroud, that the ascorbic acid present in living leaves is responsible for the reaction. It was demonstrated that chloroplasts in leaves killed by chloroform, toluene, and formaldehyde fumes and by temperatures of -50° C. to -30° C. and by 100° C. in dry air lose their reducing powers. As indicated by the dichlorophenol-indophenol reagent, the ascorbic acid present in the living leaves was destroyed when leaves were killed in this manner. If, however, leaves were killed in a similar manner, except that an atmosphere of hydrogen replaced that of ordinary air, the reduction of silver nitrate was still effected. The indophenol test indicated that ascorbic acid was present in the extract obtained from these leaves. When clover leaves were killed in boiling water the ascorbic acid was not destroyed and the chloroplasts were still able to reduce silver nitrate. In some preliminary studies on pure ascorbic acid it was noted that

the silver nitrate was reduced rapidly and energetically when the pH of the ascorbic acid solution was 7 or higher, but very slowly when the pH was 4 or below.

Sorrel and *Oxalis* leaves, with a sap of pH 2 or lower, and clover leaves which had been killed in 8 per cent acetic acid would not reduce silver nitrate although ascorbic acid was present. Neither would the acid pulp of lemon and pineapple reduce silver nitrate, although ascorbic acid was present. The more alkaline rind of lemon strongly reduced silver nitrate and contained ascorbic acid. In these cases ascorbic acid was present but, owing to the low pH of the cell sap of sorrel and *Oxalis* leaves and the pulp of lemon and pineapple and of the acetic acid killing solution, silver nitrate reduction was not brought about. The more alkaline condition of the lemon rind does not prevent its reduction by the ascorbic acid present in this tissue. These observations indicate that ascorbic acid is responsible for the reduction of the silver nitrate by the chloroplasts and suggests that it is confined to them. This latter statement is, however, open to question, for it is possible that the ascorbic acid is generally present throughout the cell and that special conditions, such as increased alkalinity, within the chloroplast itself may account for the more intense reaction in that body. Of particular interest is the oxidation of the ascorbic acid which occurs immediately upon death of the cell. This reaction does not take place in the living cell or, if it does, does so at a very slow rate, even though the reacting substances are within proximity.

CARBON DIOXIDE ABSORPTION BY UNILLUMINATED LEAVES

In the process of photosynthesis as carried out by the higher plants, carbon dioxide of the air is absorbed by the leaves and transformed into carbohydrate under the influence of light. The leaf must possess a system for absorbing the carbon dioxide prior to its transformation by light. Previous researches have shown that the carbon dioxide of the air enters the leaf primarily through the stomata. From the time the carbon dioxide passes through the stomata until it appears in the form of carbohydrate virtually nothing has been known of its activity.

The hypothesis has been proposed that chlorophyll reacts chemically with carbon dioxide and the compound thus formed, under the influence of light, is converted into carbohydrate. Because of the importance of this concept to the formulation of a correct theory of photosynthesis, this aspect of the problem has been given special consideration. It was found that, although pure chlorophyll dissolves carbon dioxide, there was no evidence in these investigations of chemical reaction between the two. Furthermore, leaves containing large amounts of chlorophyll show no more affinity for carbon dioxide than leaves completely lacking in this pigment, i.e., luteous, albino, or etiolated leaves. The earlier experiments purporting to show interaction between pigment and carbon dioxide can be explained by the physical solubility of carbon dioxide in the pigment.

It has been assumed that the magnesium atom in the chlorophyll molecule is the point of combination of the carbon dioxide with the chlorophyll. This assumption appears to be doubtful, however, because removal of the mag-

nesium from the chlorophyll, to form pheophytin, increases rather than decreases the solubility of carbon dioxide in the pigment.

No evidence has been obtained from these experiments for the formation of a compound between chlorophyll and carbon dioxide. Nevertheless, experiments carried out several years ago demonstrated that even in the absence of light, some leaves contain substances which absorb carbon dioxide. This indicated that leaves possess a chemical system for obtaining carbon dioxide from the air. Since sunflower leaves had been shown to have this system highly developed, an intensive study of the carbon dioxide absorption process in these leaves has been undertaken.

Initial observations showed that leaves killed by freezing absorbed more carbon dioxide than living leaves. On the other hand, killed leaves contained less carbon dioxide bound in chemical combination (e.g., carbonates and bicarbonates) than living leaves. However, these two properties complemented each other, so that when both living and killed leaves were saturated with carbon dioxide, at one atmosphere of pressure, the amounts of carbon dioxide bound by both were the same.

These facts indicated that the ability to bind carbon dioxide is not a function of the life processes of the leaf, but of some purely chemical system contained therein. Analysis revealed that the carbon dioxide absorption system was divided between the sap and solid material of the leaf.

The carbon dioxide fixed chemically by the sap appeared as bicarbonate ion. The formation of the bicarbonate ion could be almost completely accounted for by reaction of the carbon dioxide with the secondary phosphate contained in the sap.

The carbon dioxide fixed chemically in the solid leaf residue could be referred to the calcium and magnesium carbonates and phosphates present. The material in the solid leaf residue responsible for combining carbon dioxide, when isolated in analyzable form, was shown to have the following composition:

CaO	51.45 per cent
MgO	1.29
MnO	0.65
P ₂ O ₅	10.86
CO ₂*	33.39
Volatile not CO ₂	3.47
Total	101.11 per cent

The presence of manganese in this material may be of special significance, as it has been found to play a rôle along with the alkaline earths in the absorption of carbon dioxide by water plants.

The reaction of carbon dioxide with the calcium and magnesium carbonates present in the solid residue of sunflower leaves has interest in another direction. When stored in an atmosphere rich in carbon dioxide sunflower leaves yield an expressed sap which is more alkaline than when they are stored in air. It is possible that this observation may be explained in the following way, however. Treatment of the leaves with carbon dioxide forms soluble

bicarbonates from the insoluble calcium and magnesium carbonates present in the leaf residue. The increased bicarbonate ion concentration represses the ionization of the carbonic acid, thus reducing the acidity of the sap. A further reduction of acidity occurs through the diffusion of carbon dioxide from the sap into the air. By this loss of carbon dioxide the alkaline calcium and magnesium carbonates are formed, which increase the alkalinity of the sap still more.

The exact manner of participation of these various carbon dioxide absorbers in the photosynthetic apparatus is still obscure. It may be of importance that they form a reservoir of carbon dioxide which may be drawn upon by the leaf. The withdrawal of carbon dioxide from this reservoir is made possible by the ready dissociation of the carbon dioxide from these compounds by which it is first absorbed.

These experiments of the past year have established one possible link between the disappearance of carbon dioxide from the air through the stomata of the leaf surface and its appearance as carbohydrate in the structure of the leaf.

AMYLOLYTIC ACTIVITY OF LEAVES

The manner in which carbon dioxide influences the rate of starch dissolution in leaves has been investigated more intimately during the past year. Concentrations of carbon dioxide which result in no visible injury to some leaves, such as those of the sunflower, exert a pronounced inhibiting effect on starch dissolution. This is not noticeable below concentrations of about 5 per cent. But with higher concentrations the carbon dioxide is increasingly inhibitory.

That the rate of starch dissolution in leaves is considerably increased through rapid loss of water from the leaves has been known for some time from purely qualitative observations. Such observations are, however, subject to the uncertainties of the qualitative microchemical tests which have been employed. This remarkable loss of starch with reduction of the water content of leaves has now been substantiated on the basis of quantitative starch determinations. Of particular interest in connection with the hydrolysis of starch under these circumstances is the fact that it results in an accumulation in the leaf of sucrose, while under ordinary circumstances maltose and glucose appear, which are the normal products of hydrolysis of starch. This rapid dissolution of starch under conditions of water deficit in the leaf is also inhibited by carbon dioxide. That the rapid dissolution of starch in leaves with relatively low water content is not due to higher temperature of such leaves because of lower transpiration, has been shown by the fact that even at 5° these leaves exhibit a remarkably high rate of starch dissolution.

The effect of carbon dioxide on the rate of starch dissolution in leaves is paralleled by the effect of this gas on the amylolytic activity. Below about 10 per cent of carbon dioxide in the air surrounding the leaf this gas appears to exert a slight stimulatory effect. With higher concentrations of carbon dioxide an increasing inhibitory effect has been observed. The carbon dioxide

also affects the pH of the leaf sap, in the sense that increased concentrations result in an increase of the pH, i.e., in a reduction of the acidity of the sap. Up to a concentration of about 15 per cent of carbon dioxide in air this effect is hardly noticeable. These are the concentrations at which there appears to be a slight stimulatory effect of the carbon dioxide on the amylolytic activity. The influence of the pH on the amylolytic activity of leaves has been reinvestigated, and maximum activity has been found to be at pH 6.3 to 6.6, although this is by no means universally true. The maximum varies with the species and for some this has been found to be as low as 5. The discrepancies in the results of various investigators may be due, in part at least, to the fact that it is impossible to predict the pH of a reaction mixture containing the leaf material from the pH of the particular buffer which is used to control the hydrogen ion concentration of the mixture. The pH of the reaction mixture must in each case be determined by means of a glass electrode or by some other suitable means. The results of these investigations are now being published.

THE QUANTUM EFFICIENCY OF PHOTOSYNTHESIS

ROBERT EMERSON AND CHARLTON M. LEWIS

The reduction of carbon dioxide to carbohydrate requires a minimum of 112,000 calories per mole of carbon dioxide. In green plant photosynthesis, the energy necessary for this process is obtained through the absorption of visible light by chlorophyll. Photosynthesis proceeds normally in red light, where the energy obtainable from a number of light quanta equal to the number of molecules in a gram-mole (one mole-quantum) is only about 40,000 calories. Several light quanta must therefore be absorbed in order to provide the minimum amount of energy required to reduce one molecule of carbon dioxide. According to the present concepts of physics, absorbed light quanta cannot act additively, but only individually, so we may suppose that each absorbed quantum effective in photosynthesis brings about a single elementary step in the process of carbon dioxide reduction. If three quanta of red light were available for each molecule of carbon dioxide, there would be $3 \times 40,000$ or 120,000 calories per mole, an amount greater by 8000 calories than the theoretical minimum of 112,000. But each individual step must require some activation energy, for which a margin of only 8000 calories would hardly be sufficient. Therefore it is generally believed that nothing less than four quanta can be regarded as providing enough energy for the reduction of one molecule of carbon dioxide to carbohydrate.

The minimum number actually required by the plant should give a clue to the number of elementary photo-processes by which the reduction is accomplished. In 1923, Warburg and Negelein published the results of experiments on the quantum efficiency of photosynthesis, indicating that under ideal conditions, *Chlorella* cells could reduce one molecule of carbon dioxide for each four quanta of visible light absorbed. This has led a number of investigators to conclude that green-plant photosynthesis in general takes

place by means of a reaction mechanism involving four elementary photo-processes.

Although the quality and precision of Warburg and Negelein's measurements have not been questioned, efforts to duplicate and extend their results have been unsuccessful almost without exception, and consequently the value of the original results in establishing the reaction mechanism of photosynthesis has been called in question. Warburg and Negelein found that the maximum quantum efficiency was obtainable only with cells which had been subjected to special previous treatment. They gave only scanty information concerning the factors which produced cells capable of high quantum yields, and none on how these factors influenced the internal characteristics of the cells. They studied only a single species of organism, and it would be desirable to extend their work to other species before drawing general conclusions concerning the mechanism of photosynthesis. The high quantum yields were obtained only at light intensities so low that respiration exceeded photosynthesis. Instead of assimilating carbon dioxide taken from the external medium, the cells were presumably using carbon dioxide produced internally by respiration. But it is also possible that instead of carbon dioxide, intermediate products of respiration were being reduced. Presumably much less energy would be required for the conversion of such substances to carbohydrate than for the reduction of carbon dioxide to carbohydrate. Finally, the results of Warburg and Negelein are indecisive on the question of the activity of the yellow pigments. There remains a possibility that they play a photochemical part in carbon dioxide assimilation.

In the fall of 1937, a new investigation of the quantum efficiency was begun. The objectives were to specify more definitely the conditions under which the high efficiencies reported by Warburg and Negelein were obtainable; to establish relationships between physiological characteristics of cells and the quantum yields of which they are capable; to extend the measurements to light intensities where photosynthesis exceeds respiration, and to lower temperatures, where respiration is minimal, in order to establish the quantum yield for carbon dioxide taken up by the cell from the outside; to improve both the intensity and the spectral purity in the red region, in the hope of distinguishing between the activity of the two chlorophyll components; to test the photosynthetic activity of pigments other than chlorophyll; and to extend our knowledge of quantum efficiency to other species besides *Chlorella*.

The first year has been devoted to the building of equipment and the development of technique. To meet the requirements in red light, a reflecting monochromator of large aperture and size will be built. A test model is now nearing completion, and it is expected that this will be sufficiently powerful to be available for quantum efficiency measurements, pending the completion of the final instrument. A number of modifications in the technique of measuring photosynthesis are being tried out. Differences in the timing of light exposures and dark periods lead to very different corrections for respiration, which in turn give important differences in the computed quantum yield, and a more thorough study appears necessary in order to establish a technique as free as possible from uncertainties.

EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESY

This year the work has centered on bringing to publication the experiments on the reactions of plants transferred to different climates as represented by the three transplant stations, Stanford University near sea level, Mather at 1400 m. elevation in the Sierra Nevada, and Timberline at 3050 m. The results have been accumulating since 1922, but the more comprehensive data on which the statistical analysis is based have been assembled during the years 1934 to 1937 after the inception of these experiments in their new form. The data are so extensive that their complete analysis is still unfinished, but the results of the investigations are clear from the studies already made.

The most significant contributions are, first, the demonstration of the delicacy of balance between the internal or gene-controlled factors and the external environment; second, a comprehension of the orderly complexity of species composition in relation to plant distribution; and third, an evaluation of the capacity of plants to adjust themselves to different environments. The intricate reaction patterns of races of one species to different climates indicate that the capacity for modification is important for the survival and distribution of a given form. The visible effects of the interplay between heredity and environment on plants are complex indeed, and the interpretation of the experimental results demands critical analysis.

REGIONAL DIFFERENTIATION INTO ECOTYPES AND ECOSPECIES

It is clear from the varied-environment or transplant experiments that heredity governs the basic differences in appearance and the capacity for survival in different habitats. Within one species, individuals of widely different hereditary composition may be found. Some species have developed races or ecotypes, each obviously adjusted in its physiology to different environments, as, for example, to coastal, montane, or alpine conditions. Such races can usually be distinguished by their morphology as well as by their reactions to different environments. Within each ecotype, individual variations of genetic nature that are often associated with minor habitat differences usually further enrich the diversity within the species.

In the region of the Pacific slope, species of wide distribution are often differentiated into four major races or ecotypes corresponding to different climatic belts of this area. These include a Coast Range, a lower montane, a subalpine, and an alpine ecotype. If the species grows along the immediate coast an additional maritime ecotype may be found, and if it extends into the Great Basin, it may there produce another ecotype. Evidently the conditions in California are so varied that four to six major changes in hereditary set-up are required if a species is to occupy the entire area from west to east. When two ecotypes meet or overlap they may hybridize and produce recombinations that survive, but as one leaves the zone of contact the parent types on both sides can be recognized by their combinations of characters and their ecological distribution. Frequently one or more ecotypes are re-

placed by closely related species, called ecospecies, that may have originally started as ecotypes.

The belts of vegetation formed by the various altitudinal ecotypes or ecospecies do not strictly follow horizontal lines but move up and down through the canyons according to local conditions. Topographic irregularities with their resulting climatic changes thus complicate the distribution of the races or ecotypes of a species.

THE REACTION PATTERNS OF ECOTYPES

When plants of a given species are taken out of their natural surroundings and moved to a different climate, they change their appearance in a manner and degree characteristic for each race or ecotype. Accordingly, at each of the three transplant stations, Stanford, Mather, and Timberline, the same collection of individuals, representing different ecotypes of one species, presents to the observer a different aspect. Foothill, subalpine, and alpine races of *Potentilla glandulosa*, for example, grow tallest at the mid-altitude station and are most dwarfed at the alpine station, while the Coast Range race is slightly more vigorous at Stanford, and, like the foothill race, perishes at Timberline. The mid-altitude, subalpine, and alpine races of *Potentilla gracilis* follow the same general trend in reaction as the corresponding ecotypes of *P. glandulosa*, but the closely related, exclusively alpine *P. diversifolia* is smaller at the mid-altitude station than at either Stanford or Timberline. *Potentilla Drummondii* has no Coast Range, foothill, or mid-montane ecotypes, but its subalpine ecotype is tallest at Stanford, near sea level, and shortest at Timberline. The alpine races of *Achillea millefolium* and *Aster occidentalis* are tallest at the mid-altitude station at Mather, like the alpine forms of *Potentilla glandulosa*, but, in contrast, become even more dwarfed at the lowland station than at the alpine.

These and many other examples demonstrate that reactions to different environments may change from ecotype to ecotype. The behavior of a given race is, indeed, quite unpredictable, and this indicates that the relation between a plant and its environment is a very complex one. This fact is of practical significance in the breeding of agricultural and forestry plants for different climates.

Besides modifications in external structure which follow as a result of changing the environment of a plant, observable adjustments in its seasonal rhythm to fit the seasons of a new habitat take place. In their natural environment, the Coast Range ecotypes of many California species grow almost continuously, developing vegetatively in winter and flowering early in spring. Alpine ecotypes of the same species, on the other hand, remain dormant for nine to ten months in their native habitat. When alpine races of some species such as *Potentilla glandulosa* or *Achillea millefolium* are brought to Stanford, the period of dormancy is reduced to two to three months, and others, like *Horkelia fusca*, remain evergreen. Coastal ecotypes brought to climates with the more severe winters of higher altitudes in the Sierras are forced into winter dormancy despite their inherent tendency to continuous growth. From this we conclude that races from different elevations change their growth with the seasons of a new environment.

EQUILIBRIUM WITH THE SURROUNDINGS

Modifications in both external morphology and internal rhythm may be advantageous to a plant in a different environment, but from the evidence accumulated in the varied-environment experiments, these modifications do not enable a plant to take care of itself very far outside its own zone.

For example, the Californian coastal ecotypes are in harmony with a climate with mild winters and a long growth period. In contrast, at the alpine station they are seldom or never able to mature seed, although they reduce their size markedly and thus tend to hasten development. Moreover, they seldom live through more than one or two winters. When they resume spring growth in July after a long, severe winter, they appear starved and are often unable to flower.

Alpine ecotypes are in harmony with a climate of long, cold winters and short growing season. There they flower shortly after spring growth has started and assimilate sufficiently to produce vigorous and floriferous plants each spring. At the lowland station with its much milder winters their relative unfitness is manifested by reduced flowering and a weakened appearance in spring following a period of dormancy substantially shorter than in their native home. Many alpenes do not even flower at Stanford.

The adaptive capacity of coastal and alpine ecotypes is therefore insufficient to allow either to live and to compete in the habitat of the other. It is the difference in inheritance that enables them to succeed in their respective regions. From these and many similar observations it is evident that the regional ecotypes are fitted to their climates. Their internal rhythm is in equilibrium with the complex demands of their environment.

CHROMOSOME NUMBER AND ENVIRONMENT

It has been suggested by several authors that a high chromosome number is associated with fitness to extreme habitats, like alpine, arctic, and desert conditions. Our findings are not in harmony with this theory as it was originally formulated.

Viola purpurea has only 6 pairs of chromosomes from 1000 to 3000 m. elevation in the Sierra Nevada, but 12 pairs in the Coast Ranges and in the Sierran foothills. The yarrow, *Achillea millefolium*, has only 18 pairs of chromosomes in the Sierra Nevada up to 3300 m. elevation and in the arid Great Basin, but has 27 along the Pacific Coast from California to Alaska. The common mugwort, *Artemisia vulgaris*, in its widest sense, has 18 pairs in the subalpine and in the alpine regions of the Sierras, in the Great Basin, and in the Rocky Mountains, but has 27 pairs in the lower regions of the Sierras and in the Coast Ranges north to the Aleutian Islands. A closely related but distinguishable form with only 9 pairs occupies a narrow coastal strip from northern California to British Columbia. In this latter instance the lowest and the highest chromosome numbers are both found in the coastal region. *Zauschneria* of the Onagraceæ has two coastal species with 15 pairs of chromosomes, and one species with twice this number that has been able to occupy not only the Coast Ranges but the mountains of southern California and the Sierra Nevada as well.

That a similar series of habitats may be occupied by one species without change in chromosome number is illustrated by *Potentilla glandulosa*. All the forms of this species have 7 pairs of chromosomes, but it has nevertheless become differentiated into four regional ecotypes, occupying an altitudinal range from near sea level to timberline.

From this and from evidence reported in the literature the conclusion may be reached that, with but few exceptions, closely related species that differ in chromosome number occupy different environments, but there is no correlation between high chromosome number and extremity of environment.

Change of chromosome number is but one mode of regional differentiation. The same end can be accomplished through development of a series of ecotypes without change in chromosome number. The primary difference between the two modes is that free interbreeding is prevented where chromosome numbers are changed, whereas no breeding barriers are created by differentiation into ecotypes. Both modes are found in *Achillea*, for example, where the 18-chromosome Sierran ecospecies has evolved a series of markedly different ecotypes.

EXPERIMENTAL RESULTS EXPRESSED IN TAXONOMY

In analyzing the data from the varied-environment experiments, it was found that the taxonomic status of almost all plant groups represented was insufficiently known. The reactions of the living plants at the three stations have given definite information on the number of ecotypes or ecospecies involved and their taxonomic limits. It is not the appearance but the fitness of plants to their environment which is the most important factor for survival. But since morphologic differences were often found to be correlated with capacity for survival, they assume added significance where such correlations can be experimentally demonstrated. In such instances it is possible to map the distribution of ecotypes from herbarium material. The taxonomic rank (ecotype or ecospecies) is being determined by the evidence of cytology, and, as far as possible, from genetics. Step by step these integrated investigations build up a picture of plant relationships useful in a critical and interpretative taxonomy.

SELECTION EXPERIMENT

An experiment which is a logical sequel to the varied-environment studies has been started this year at the Stanford, Mather, and Timberline transplant stations. An F_2 population of a cross made six years ago between the Sierran foothill and the alpine ecotypes of *Potentilla glandulosa* has been grown to maturity (see Year Book No. 36, 1937, p. 213), and each of the six hundred plants was divided into three parts. One set of this triplicate population was planted at each of the transplant stations this summer, and individual records are being kept of each member.

It is the object of this study to determine which types survive in each of the three sets of environments, and to observe their mode of reaction. It has already been found that the foothill parent succeeds at Stanford and at Mather but fails to survive at Timberline. The alpine parent, on the other hand, thrives at all three stations, especially at Mather and Timberline. The

F₁ hybrid survives at Timberline but not nearly as well as the alpine parent. Because the F₂ population represents an interchange of genes of two very different climatic ecotypes, and includes segregants representing both parents as well as a host of recombinations, this experiment should test the theory of adaptive evolution by genetic recombination and selection.

OTHER INVESTIGATIONS

Continuing his exploratory investigations on transpiration of plants representing different altitudinal ecotypes of *Potentilla gracilis*, Mr. Hiesey has found differences, the significance of which is the subject of further study.

Dr. Åke Gustafsson of the Genetics Institute of the University of Lund, Sweden, investigated the cytology of the species of *Horkelia*, including those used in the varied-environment experiments, while he was visiting the Central Laboratory at Stanford. As far as his work has progressed, he has cytological confirmation for the taxonomic conclusions reached by Dr. Keck, who, in connection with the analysis of the varied-environment experiments, has revised the genera *Horkelia* and *Ivesia*.

The preparation of a flora of the Harvey Monroe Hall Natural Area has continued during the short stays of the staff members at the Timberline station. The area includes about seven square miles varying in altitude between 3000 and 3800 m. The flora is rich for such a high elevation; more than 280 species have already been found in the preliminary surveys, 155 of which are of northern distribution, 31 extending to Alaska and 32 being circum-polar. That many of these species are near the southern limits of their distribution is of particular interest.

INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

I. W. BAILEY

Generalizations concerning the internal structure of the vascular plants and its functional significance, when based as is commonly the case upon an *intensive* study of a few selected species, should be checked by an *extensive* investigation of a wide range of representatives of various families and orders. We have shown, for example, that it is misleading and quite fruitless to attempt to homologize all types even of commercial plant fibers in a single structural model as various workers have attempted to do. A study of the comparative anatomy of gymnosperms and angiosperms shows that the walls of plant fibers are extremely complex and variable and exhibit various fundamentally diverse structural patterns. Similarly, the physical properties and the chemical composition of the plant cell wall fluctuate greatly not only in different representatives of the gymnosperms and angiosperms, but also at times in different parts of the same plant.

In the case of the cambium and its derivative tissues, it is essential to assemble authentic specimens from a wide range of gymnosperms and angiosperms, from different phytogeographical regions, and from plants of diverse form and habits of growth. Yale, Harvard, Oxford, and other institutions are now cooperating in assembling such specimens. The inves-

tigation of material of this character, although a task of considerable magnitude, should ultimately provide not only a much clearer picture of the salient lines of structural specialization and evolution in the higher plants, but also an essential basis for testing various generalizations concerning the functional activities of the cambium, xylem, and phloem. At present, we are engaged in the study of (1) the tracheary cells of the xylem, which are concerned in the upward movement of sap, and (2) the parenchymatous elements of the xylem, which are considered to be physiologically significant primarily in the storage of elaborated material. In addition, Dr. A. S. Crafts, Guggenheim Fellow, is making an extensive investigation of the sieve tubes of the phloem, whose functional activities are the subject of so much controversy among students of the downward movement of elaborated materials. More extensive and reliable information concerning the structure and the activities of specific cells and tissues should eventually provide a clearer picture of the integrated activities of the plant as a whole.

DESERT INVESTIGATIONS

FORREST SHREVE, T. D. MALLERY, AND W. V. TURNAGE

The Desert Laboratory is devoted to the study of a particular environment and its plant life. The work involves thorough investigation of the environment as well as knowledge of the behavior of plants. The most fruitful results are obtained when it becomes possible to establish a close relation between environment and plant. In past years considerable work has been done on the rôle which the broader climatic conditions play in controlling the distribution of plants. In recent years increasing attention has been given to the detailed differences of climatic and soil conditions which often manifest themselves in a very small area. The smaller and local features of climate are of importance in the distribution of plants, especially in their selections of habitat, but have even greater importance in controlling the life of the individual plant. The tendency of the work at the laboratory has been away from the viewpoint of plant sociology and toward the study of the life history and behavior of the individual plant. The importance attached by many workers to the social features of plant communities is largely subjective, and indeed somewhat homocentric. The relation of the desert plant to its physical environment is very real and extremely important, and has a far more vital bearing on the interpretation of the vegetation than do its relations to the biotic environment.

Substantial progress has been made during the past year in the study of the life histories of plants as well as in the investigation of climatic and microclimatic features of the desert environment. Some of the recent results of these investigations are already published or in press.

THE SONORAN DESERT PROJECT

The five-year program of field work on the Sonoran Desert was concluded at the end of 1937. Much of the past year has been spent in study of living and herbarium material secured during the period of exploration of the

area, and in working over field notes and other data for publication. It is planned to prepare companion volumes dealing respectively with the flora and the vegetation of the Sonoran Desert.

Adequate treatment of the vegetation necessitates description of the physical features of the area, including its geography, physiography, soils, and climate. Maps are being prepared to show these features on the basis of our own and previous work. This has been found to involve compilation from various sources and much detailed work. Maps are also being prepared to show the distribution of types of vegetation and important species or genera. In addition to description of the various types of vegetation, a group of about 100 plants of importance in the composition of the vegetation will be given individual treatment, covering their gross anatomy, seasonal behavior, habitat preferences, and as much as can be learned about their life histories.

One of the distinguished features of the Sonoran Desert is the relatively large number of growth forms, or life forms, which are represented among the dominant plants in its vegetation, doing much to give the physiognomy of the desert landscape its striking character. A careful study of the life forms has been made and a series of 25 is now recognized for this area, constituting a rough physiological classification of the plants irrespective of their phylogenetic relationship. If a classification of life forms is to have more than mere utility in the description of vegetation, and is to be of service in interpreting the relations between plant forms and environmental conditions, it is necessary that it be based only on criteria of known physiological significance. In contrast to the large number of life forms in the Sonoran Desert it is to be noted that there are but few life forms among the dominant plants of more favorable regions. The view has been developed that the existence of highly competitive relations between plants in favorable climates has resulted in standardizing the dominant types. In the far less competitive conditions of the desert there has been an opportunity for the independent development of very dissimilar types and also a favorable condition for the long survival of the unstandardized types. The study of the life forms, the known stages in their origin, their distribution, and their relation to environment, bears promise of being significant in the interpretation of the history of the plant life of the region.

Work on the flora of the Sonoran Desert, which is in the hands of Dr. I. L. Wiggins, of Stanford University, has been actively pursued during the year. Dr. Wiggins spent the months from June to December 1937 at the Royal Botanic Gardens, Kew, at the Gray Herbarium, Cambridge, and at other taxonomic centers, studying the types of species described from older collections in the Sonoran Desert. It was particularly important for him to examine the types of the many plants of Baja California which were first collected on the voyage of the *Sulphur*, in 1839, and those collected in Sonora by Thomas Coulter in 1830. Keys which have been prepared by Dr. Wiggins for a number of difficult genera have been placed in the hands of several workers in order to test their soundness. Several taxonomists are generously preparing treatments for Dr. Wiggins of families of plants in which they have specialized.

Mr. H. S. Gentry has spent part of the year at the Desert Laboratory working on collections of plants made by him during the past four years in the valley of the Rio Mayo in southern Sonora. He is preparing for publication an account of the vegetation of the lowland and mountain region which he was the first botanist to explore, and an annotated list of about 1600 species of plants based on his collections. The lowland part of the territory covered by Mr. Gentry is adjacent to the southern end of the Sonoran Desert, which has made his observations and collections of great value in connection with the work on that area. His knowledge of Sonora and parts of Baja California has also enabled him to give substantial help in the current work on the Sonoran Desert.

FIELD INVESTIGATIONS

Several brief trips have been made during the year into the lower elevations of the Sonoran Desert and into the Mojave Desert to make observations and comparisons of plant behavior at suitable seasons. In July 1937 a trip was made by Dr. Shreve, Dr. Mallery, and Dr. L. R. Dice, of the University of Michigan, through the state of Chihuahua. The first purpose of the trip was to find out the degree of similarity or difference between the Sonoran and Chihuahuan Deserts, and the second purpose was to secure a basis for considering the desirability of doing more work in the latter area.

South of the international boundary the Sonoran and Chihuahuan Deserts are effectively separated by the forested Sierra Madre Occidental, but north of the boundary the only barrier between them is a broad expanse of arid grassland plains. Many plants characteristic of the northern ends of the two deserts are also found in the arid grassland, but a larger number have not crossed the barrier region. The Chihuahuan Desert is much poorer than the Sonoran in its types of small desert trees. It is also poorer in the display of succulent plants and lacks many of the life forms which are abundant in the latter area. Although having a groundwork of similarity, the two deserts show strong contrast in many features of the structure and habital distribution of their plant communities. A paper is in press which describes briefly the vegetation of the part of the Chihuahuan Desert which lies in the state of Chihuahua.

ENVIRONMENTAL CONDITIONS

Investigation of physical conditions during the year has been marked by the discontinuance of certain observations that have yielded the desired results, and by the extension of others in which greater detail or broader basis of comparison is needed.

Rainfall records have been taken for periods of three to thirteen years at lines of stations across the Sonoran Desert, at equal vertical intervals across five mountain ranges, and at eight localities within a square mile of the laboratory grounds. Taken in conjunction with the data of the United States Weather Bureau and the Mexican Meteorological Service, the available figures have made possible an analysis of the rainfall conditions which is now in preparation for publication. As a result of this work the line of stations along the Camino Del Diablo and those on two of the more distant mountain ranges have been discontinued.

In Arizona and northern Sonora in each of the two rainy seasons three geographical regions are recognizable which differ in the relation of altitude to rainfall. In winter the wettest section, relative to altitude, includes the Sonoran Desert and the Mogollon Mesa, next is southeastern Arizona, and the driest is northeastern Arizona. In summer the region which is wettest in relation to altitude includes the desert, southeastern Arizona, and the southwestern slopes of the Mogollon Mesa; next are the northeastern slopes of the Mogollon Mesa, and the driest section is northern Arizona. Abrupt topography often serves to induce rain, and more so in winter than in summer. Illustrations include slopes immediately to leeward of high mountains of small mass, narrow valleys and pockets surrounded mainly by higher land masses, and also high mountain slopes.

Relative to elevation, rainfall in summer decreases on passing from southeast to northwest. In winter the maximum is found in the lower Gila Valley, with a decrease on passing northwestward. Near Tucson, on an area of one square mile the irregularities of summer rainstorms are smoothed during a season. The smoothing of the winter rainfall is not so great and it is therefore more variable over a small area than the summer rain. Over larger areas the rainfall of a given summer is more unequally distributed than that of winter. The departures from normal of a season of rain from place to place over the region considered are irregular, only very dry or very wet years showing high uniformity. When the individual departures are summed and divided by the number of stations, in order to obtain a composite picture of the regional variation from year to year, the winter rain is found to vary from the normal more strikingly than does the summer rain.

Routine readings of soil moisture and runoff have been continued on the revised plan adopted early in 1937. These observations are making it clear that the moisture content of the soil below 2 to 3 feet over the general surface of the desert is very rarely built up by even the heaviest rains. The percentage of runoff in summer ranges from 40 to 62 per cent of the rainfall yield, and in winter from 5 to 29 per cent. During the past four years the total runoff has been 38 per cent of the total rainfall. Schwalen has shown that the stream flow of the Santa Cruz River and its principal tributary, the Rillito, draining over 3000 square miles of desert and desert grassland, is "less than 2 per cent of the total precipitation." These figures indicate that about 36 per cent of the precipitation penetrates the soil between the place at which it falls and the minor drainageways or else in the sandy beds of the small tributaries of the principal rivers. It also indicates that little more than 2 per cent of the rainfall finds its way into situations where it is likely to contribute to the ground water of the central flood plain of the Santa Cruz Valley. These considerations are illuminating with reference to the water supply for perennial plants of flood plains and the margins of streamways. They have little application, however, to the conditions for plants of rocky slopes and hills, where many practical difficulties have deterred investigation.

The investigation of soil temperature has necessitated selection of instrumental equipment suited to the very dissimilar conditions of the surface,

where high daily ranges prevail, of levels from the surface to 3 feet, where a smaller daily range occurs, and of levels below 3 feet, in which there is no daily range and only a small annual one. A Foxboro thermograph was installed in 1937, suited to record the high range of a shallow level. Friez soil thermographs have been in operation at 3 inches, 1 foot, and 2 feet, and weekly thermocouple readings have been taken at 3, 6, and 12 feet. All these instruments are in the clay soil of the Santa Cruz flood plain. Accuracy, simplicity, and moderate cost of the instrument employed have been best attained for depths below 3 feet by use of thermocouples and portable galvanometer. Insulated thermocouple wires in the soil at depths of 3, 6, and 12 feet have not changed their constants during a year of use, and furthermore can be calibrated in place at any time. The importance of careful instrumental exposure is shown by comparison of records taken for 12 months at 6 feet by thermocouple and by a mercurial thermometer placed in a metal tube running horizontally into the soil from the insulated cellar of the percolimeter. The latter instrument has shown an annual range 35 per cent greater than the thermocouple.

BEHAVIOR OF DESERT PLANTS

In the course of field work in the Sonoran Desert a large collection of seeds was made, representing many of the common perennials of the lower altitudes and southern part of the area. The germination requirements, characteristics of the seedling, and early growth are totally unknown for most of these plants. During the spring of 1938 a systematic study of this material was begun. Up to the present time 90 species have been subjected to culture and observation under uncontrolled greenhouse conditions without special seed treatment other than dusting. Of the species planted about 45 per cent gave no response and will require various treatments to break their dormancy and stimulate germination. A temperature of 80° F. or higher is required to start germination in most of the species studied. Best growth is obtained when the minimum temperature does not fall below 50° F.

The seedling stage of some of the most highly specialized desert perennials shows very little resemblance to the adult plants as found in nature. This is strikingly exemplified by *Holacantha Emoryi* and *Canotia Holacantha*, leafless green-stemmed trees which bear numerous well-formed leaves in the seedling stage. A number of other highly modified forms give evidence of their phylogenetic relationship in their juvenile foliage but do not suggest it in the mature leaves. In the small tree *Acacia Willardiana* the pinnate leaves characteristic of the genus are found in the seedling, while the leaf functions are carried on in the mature tree by broadened petioles which are simple and entire in form. This transformation is common among the acacias of South Africa but no other case is known in the desert of North America.

A number of small trees develop an enlargement of the stem very early in the course of seedling development, including *Ipomœa arborescens*, *Erythrina flabelliformis*, *Bursera* spp., *Fouquieria peninsularis*, and *Idria columnaris*. The enlarged portion may extend from below the soil level and taper sharply toward the top or it may develop in the region of the seed

leaves, tapering toward both the top and root, imparting a spindle shape to the young plant.

Plants raised from seed which have become well established in the greenhouse are then transplanted to the garden or other favorable places on the grounds. The number of species under observation which were raised from seed in previous years or collected as living material is about 240. This material is helpful for the identification of plants found at seasons when they were not in flower or fruit, and gives opportunity to observe the development and growth of many species found in the distant parts of the Sonoran Desert. In a few cases unknown plants have been raised from seed, brought to maturity, and identified, among them the large-fruited asclepiadaceous vine *Mellichampia ligulata*. A number of plants have been raised in sufficient quantity to furnish material for anatomical study. The structure of stem and root is almost completely unknown in this group of plants, and the derivation of tissues and the relative proportion of medulla or cortex involved in the striking specializations require investigation.

No broad generalizations can yet be made from the study of the early life histories of the plants now under observation. At present the results consist essentially in a record of details with reference to each plant. It is already evident, however, that the diversity which is manifested in the life forms of the Sonoran Desert is also found to extend to their seeds, modes of dissemination, germination, and early development.

For a number of years the growth and reproduction of the creosote bush, *Larrea tridentata*, has attracted investigation. In the characteristic evenly spaced stands of this shrub the majority of the individuals appear to be old and slow of growth, and natural reproduction to be very poor. It has frequently been noted that removal of the shrubs or disturbance of the surface is followed by the appearance of many young plants. In 1928 a series of eight areas 15 m. square was laid out and subjected to different treatment (as reported in Year Book No. 29, 1930, p. 225). After the summer rains of 1929 it was found that reproduction had been most active on the area in which the surface soil had been turned over to a depth of 10 cm., and much less active on areas which had been vigorously raked or covered with new soil. The number of seedlings that appeared in these areas was respectively 136, 14, and 10. No reproduction took place on the control areas and the influence of the removal of old bushes was slight. In 1938 the number of seedlings surviving on the above three areas was respectively 42, 9, and 10, and 3 additional ones had appeared on the control areas. Most of the 1929 seedlings now vary from 5 to 15 cm. in height, but a single one has reached 137 cm. The widely scattered crop of induced seedlings was reduced to 37 per cent of its original number in 10 years. The appearance of 3 new plants on the 1800 sq. m. in 10 years probably indicates the normal rate of reproduction under undisturbed conditions.

In 1930 a small area on the grounds of the laboratory was noticed to have a very heavy stand of young creosote bushes, apparently induced by the shallow excavation of an Indian village site ten or fifteen years before. An area 9×15 m. in size was mapped and the maximum height of each of the 226 plants was recorded on the map. This area was remapped in 1938. Ten new

plants had appeared and 15 of the original ones had gone. The growth was plotted, showing a mean height increase of about 50 per cent, 61 individuals having made this or a greater growth. There were 51 plants which were not as high as in 1930, having been eaten back repeatedly by rabbits. Plants which were less than 50 cm. high in 1930 suffered more from rodents than taller ones. Later observation of this area will show whether it thins out to a stand of normal density as the plants become older and larger, and the results will have an important bearing on the question of competition or independence in desert plants. The elimination of only 5 individuals in a population of 226 over an eight-year period gives some indication that the selective processes of competition for light and soil moisture are not strong, and are indeed subordinate to the deterrent influence of rodents.

In June 1926 Godfrey Sykes began measurements of height growth of the sahuaro (*Carnegiea gigantea*) at a place on the grounds where they exhibit their maximum abundance. His method of measurement involves a cement datum point and avoids the thickly clustered spines at the apex. Readings have been continued for twelve years on his series of 9 plants of various heights. For three years the measurements were taken monthly. Height growth varies from 3 to 4 inches per year except in the plants less than 12 inches in height, which grow much more slowly. The monthly readings show that growth takes place only during the summer rainy period, whereas during the dry spring months there is often a slight shrinkage.

The mesquite tree (*Prosopis velutina*) reaches its greatest size and abundance on deep flood-plain soils. Leaves appear and shoots begin to elongate in March or early April, at the time of greatest atmospheric aridity, but increase in trunk diameter is confined to the summer rainy season. The performance of the mesquite has been followed for the past eighteen months and changes of stem diameter measured by the dendrometer. Concurrent records of rainfall, infiltration, soil moisture, and soil temperature close to the measured trees make it possible to evaluate the principal variables which affect growth. Trunk swelling is minute after rains of less than 0.25 inch, and appreciable shrinkage has followed light rains in the dry season. Swelling follows all heavier rains throughout the year, but in winter is soon followed by compensating shrinkage. Growth of leaves and shoots is made when the surface soil is dry, but the greatest increases of trunk diameter follow the wetting of the surface soil by heavy rains in midsummer. In twelve months the net increase in diameter of a stem of 10 cm. was 0.8 mm. The water table beneath the measured trees is about 45 feet below the surface. If the roots reach that depth they do not secure enough water to cause trunk growth.

ECOLOGY

FACTOR AND FUNCTION IN ADAPTATION

F. E. CLEMENTS, F. L. LONG, AND E. V. MARTIN

In the early investigations of adaptation by means of the transplant method, it was found that the various environments operated not so much as a complex but rather in terms of a major factor modified in turn by several other factors. Change of altitude in itself did not modify growth rate and

stature, but only in those cases where the water relations were significantly different. Alpine dwarfs native at 12,000–14,000 feet on Pikes Peak remained dwarfs in dry situations, whether at the Alpine Laboratory at 8000 feet, the Plains Garden at 6000 feet, or near the sea level at Santa Barbara. Likewise, the transfer of tall plants from low to high elevations produced dwarfing in the dry climax areas, but not where moisture was more abundant. Even in the relatively moist spruce forest, alpine species usually remain diminutive, except when the water content of the soil is fairly high.

The explanation of this general behavior has been found in a series of control experiments with graduated amounts of water and of light. In all of these, stature increased with the percentage of water available, while in the case of light the maximum height occurred at 25 per cent of sunlight and fell off both toward sunshine and toward the lowest intensity of 6 per cent. This is apparently to be explained by the correlation between the tension due to turgor and the amount of growth materials supplied by photosynthesis. With respect to mineral nutrients, the results were somewhat similar; branching was greatest and dry weight highest with the largest dosage of fertilizer, but plants in the intermediate condition were tallest. Temperature has been found to promote woodiness and to increase the life span, but as a rule its specific effects are less definite than with the other three factors, while humidity and wind are chiefly concerned in water relations.

As a consequence of the combined study of factors and functions, the experimental system has steadily assumed more definite form, and the adjustment between nature and control is expressed in four successive stages, namely: (1) native habitats; (2) slight control, chiefly watering during drought periods; (3) moderate control by means of dry and wet gardens, shade tents, lath houses, etc.; (4) practically complete control of water, light, nutrients, soil, length of day, and so forth. In all of these, a single factor, water, light, or nutrients, has been the chief agent of modification and the others have been equalized in whole or in part. Through many replications by species and seasons, this study has led to more or less definite correlations between factor, growth, and form, reinforced by the measurement of functional response in phytometers. However, it is essential to link together factor and form in a large number of transplant species by means of functional determinations, and this task is now well begun.

Of the three major factors, water has been found to be the most important qualitatively, followed somewhat closely by light, while nutrients are mostly quantitative in effect. Transpiration is measured with much accuracy under field and garden conditions by weighing sealed or free phytometers. The primary difficulty is found in transferring native and experimental plants to containers safely and in growing them from seedlings in phytometer cans. Hence, in the more difficult cases, recourse is had to short-period potometers of shoot and leaf, weighing detached leaves, cobalt paper, etc. These yield approximate values, which can be improved by projecting them against the readings from standard phytometers. In the case of photosynthesis, the method of gas analysis is hardly practicable in the field, and the determination of photosynthate and dry weight yields the best correlation with the various light intensities.

Such direct factors operate immediately upon the vegetative body and their effect upon the reproductive organs is exerted for the most part through the food stream. Marked or extreme dosages are usually reflected in the size, number, or arrangement of flowers, but deep-seated changes in flower or fruit are more readily induced by the manipulation of the food current itself. This is accomplished in a variety of ways, by severe pruning, by excision, by compressing, by injecting glucose, vitamins, poisons, etc., with the result that nearly all species thus treated have shown fundamental alterations in number plan, the regeneration of staminodes and pistillodes, or the reduction or abortion of stamens, pistils, or perianth. The specialization that has produced the social flowers of grasses and composites has provided the most fertile field for both direct and indirect modification. This is not merely because of the longer line of evolutionary steps to be retraced, but especially because the spikelet and head are relatively recent structures, into which vegetative parts such as bracts and scales have been built. Consequently, the glumes and lemmas of grasses and the involucre bracts and chaff of composites respond to water and light much as do their prototypes, the leaves of a shoot.

Although instrumental and phytometer records have been made annually at the Alpine Laboratory for two decades, the study of the process by which functions call forth adaptation has demanded a more complete installation specially fitted to the comprehensive series of fourteen climatic and edaphic gardens. This has been carried out during the past two seasons and continued in part during the current year. For the three climatic gardens, the relative transpiration on the basis of leaf area was 10 at the plains, 6 at the montane, and 4 at the alpine station. At all the gardens transpiration in the lath houses with 25 per cent light intensity was approximately one-half that in the sun. There was a marked difference between the dry weights in the sun and in the lath houses at the climatic stations, namely, 100 times greater at the plains, 10 times in the montane, and 4 times at the alpine, the striking reduction with altitude being a response to decreasing temperature. With respect to nutrients, the native gravel soils gave dry weights of 20, 10, and 1 respectively from plains to montane and alpine, while in an imported sandy loam the figures were 100, 33, and 1. This decrease with elevation is partly a matter of water, but largely one of temperature, the seasonal average being 7° C. less at the montane and 20° C. less at the alpine than at the plains.

The five-year intensive study of factors and functions on wandering and stable dunes along the seacoast at Santa Barbara has been concluded and it is expected that the results will be published during the year. The dune project as a whole not only possesses high intrinsic value as the investigation of a distinctive habitat and its succession, but gains further interest because of certain similarities with alpine situations. The general assumption that the dwarf and procumbent forms of dunes are a response to arial factors has not been supported by the results, which indicate that soil factors, both water and nutrients, are the primary control. However, the fact that species grown in the series of three different soils in the main garden and on stable and wandering dunes show the highest osmotic concentrations in the latter indicates that air factors are not negligible. Survival is much the lowest in

the shifting sand, and only a few species, mostly shrubs, are able to pass successfully through the long dry season. Annuals show a much lower mortality in stable sand, while perennials that persist through the first year usually become permanently established. In some cases at least, this is due to the ability of the roots to follow the retreating water table of the rainy season downward from the 1-foot to the 6-foot permanent level. The general conditions are favorable to the accumulation of woody tissue and a number of annuals have developed into evergreen half-shrubs. This is in accordance with the high survival noted for transplanted shrubs.

With the object of throwing further light upon the fixity of stature and other characters in alpine dwarfs and lowland "talls," reciprocal transplants have been made of a selected group of species each season for a period of three years. During the present season, the transfer of the alpine species was made as soon as they appeared above ground, with the purpose of determining what changes take place during the first summer. Owing to the much later renewal of growth in the alpine zone, lowland plants could not be removed immediately upon emergence, but this was done while they were still short. Care was taken to reduce the shock of transplanting to the minimum and the response of the plants in continuing growth indicated that this had been accomplished. At the same time, the alpine species were also transplanted through a transect of five habitats in the alpine climate, but with varying water contents. Final results will not be available until the end of the growing season, but the initial response of many species indicates that adaptation to the new situation may occur more or less completely during the first year.

Timely rains in the Pikes Peak region have brought forth a larger number of modifications than has been the case in the several dry years that preceded. The majority of the morphological conversions have concerned grasses. *Sporobolus airoides* has been changed into *S. Wrightii* after two years of excess rainfall in the dunes, and the European *Agropyrum caninum* into *A. subsecundum* by transfer to half-shade. *Trisetum montanum* has been converted to *spicatum* in the sun; *Elymus ambiguus* with 2 spikelets into *condensatus* with 3-4 at a joint under optimum conditions of water and nutrients; and *Bouteloua curtipendula* into *uniflora* as a consequence of renewed blooming in midwinter. Special attention has been paid to methods of modifying the major criteria employed to separate species; thus, the triangular calyx lobes of *Amorpha fruticosa* have been changed to the acuminate ones of *A. californica* by heavy watering. This has also called out dwarf racemes with minute flowers two to three months before the leaves instead of with them and has produced decumbent rooting stems. Cushion plants typical of the alpine tundra have developed stems and peduncles many times longer than normal, and in some the trailing stems root at the joints. This feature has been called forth in a number of forbs by reduced light or increased water, and the decumbent habit has been induced in a number of perennial grasses. As usual, extreme conditions or manipulation have led to striking changes, as in the number plan of *Ruta*, the ratio of staminate to perfect flowers in *Scandix*, and the production of regular flowers with the conversion of staminode to stamen in *Scophularia*.

The greater number of the species and many of the genera made use of in the transplant and other experiments in adaptation and origin have not been examined for chromosome numbers. A comprehensive program in this field has been initiated and it is hoped not only to ascertain the numbers for many of the species concerned but also to discover whether the various methods of manipulation produce any changes in number of chromosomes.

CLIMAX, SUCCESSION, AND CONSERVATION

F. E. CLEMENTS AND E. S. CLEMENTS

The climatic cycle of the past ten years has recapitulated in miniature the much larger cycles of postglacial times and the more remote geological past. This is particularly true of the protracted drought phase with its marked effect upon vegetation and soil, and the human responses that depend upon them. The period has not been sufficiently long for vegetation to exhibit migration on the same large scale as in the past, but local migration, destruction of species populations, changes of composition, and modification of form have all occurred in prairie and plains since the advent of dry years. These have furnished support in dynamic terms to the basic ecological thesis that the major communities of the globe and their constituent species are responses to the great climates and that they migrate and evolve as the climates shift during long periods. In other words, each climax, as well as its more recent subdivisions, springs from an earlier vegetation through the further evolution of its dominant species under climatic stress. Hence, the endeavor to reconstruct the phylogeny of climaxes and the climatic pattern of geological periods necessitates retracing the migration and evolution of the species of trees, grasses, and herbs that give each its character. Such results are flowing in increasing measure from the experimental studies carried on in the transplant gardens, and these serve an additional purpose in disclosing the complex nature of vegetation and the processes that occur in it. Out of these investigations has come the ecological basis for utilizing the vegetative cover as the chief tool in conservation.

To understand the rôle of cover both as an object of conservation and as the chief method in it, it has been necessary to turn to the life form and life history of the major species, as well as to the dynamic processes concerned in succession. For example, in the mixed prairie of the Great Plains, each important species or dominant possesses its own habit of growth and growth form, exerts its particular reaction upon the soil and upon water, and manifests its own type of competition and cooperation with the associated dominants. They form an organic whole, in which no one part can be changed or removed without affecting all the others, a principle that has served to explain some unexpected results in attempting to modify or restore cover in conservation projects. Succession, both climatic and edaphic, is a universal and inescapable process, and its detailed course must be understood to permit its control or guidance. The general significance of all these features to the restoring of overgrazed pastures and to recovery in abandoned fields has been pointed out in the previous report. During the past year, much attention has been given to methods of supplementing

the natural processes by means of furrows and trenches, which promise to shorten greatly the length of time necessary for succession.

The installation of the pasture furrow by the Soil Conservation Service during the past four years has been carried out on such a vast scale, amounting to many thousands of miles, that it has been possible to study its performance in practically all the grassland communities. The results have confirmed the assumptions drawn from the ecological investigation of dynamic processes in each type. In a complete grass cover, the stems and leaves intercept some part of the rain and together with the litter retard movement so that nearly all the water is led into the soil by means of the roots. Under such conditions, the silt and fine organic matter are held in position to maintain the normal soil structure. Cover exerts a similar control of the surface soil by reducing or eliminating the force of wind. These desirable effects are diminished as the cover is impaired by grazing, fire, or drought, and it becomes essential to reinforce the grasses by means of mechanical aids.

The primary question thus becomes one of the size and spacing of the furrow to be employed. Sheet erosion, gullyng, and flooding must be prevented, water and nutrients retained and absorbed into the soil, favorable conditions provided for the germination of seed, and the soil disturbed as little as possible, in order to prevent a succession of weeds. Large contour furrows meet these requirements more or less imperfectly, since their chief value lies in holding back heavy rains to prevent accumulation into flood proportions. With spacings of 30 to 100 feet, too much water drains into the ditch and away from the slope where it is needed, carrying with it silt and organic matter. The ditch first becomes a pond, then a mass of colloidal material, and finally a miniature desert with an almost impervious soil, in which seedlings soon perish. The ridge or berm washes into the furrow on one side and over the grass on the other, and this bare area becomes the site of a weedy growth, of little or no value as forage or protection and barring out grasses by competition for a number of years to come. When wheat grass or buffalo grass is present, a thin band of regeneration may appear at the edges of the ditch and the base of the berm, but this is of little importance by comparison with the width of the drained interval. Furthermore, the amount of surface taken out of production by furrow and ridge may exceed 20 per cent when the interval is 20-30 feet, thus rendering the furrow still less adequate to the needs.

In the task of remedying the defects of large furrows, the experimental plots have been based upon the assumption that the best device will hold practically all the rain where it falls, at the same time preventing washing of the fine surface material. Other desirable effects are to spread the soil so that it serves as fertilizer instead of burying a wide band of cover, to leave roots exposed in the trench to act as channels of absorption, and to prune the roots and thus stimulate their growth. Finally, the shallow trenches catch grass seeds and litter and form excellent seed beds. In the initial tests, the intervals were set at 6, 3, and 1.5 feet, and the trenches were respectively 6×4 , 4×3 , and 3×2 inches wide and deep. The outcome indicates that the closest spacing produces the best results in accordance

with the expectation, and that the larger dimensions are best for the trench, depending in some degree upon soil and condition of cover. It has also been found that much the most rapid recovery occurs when sod grasses are present, and this suggests the desirability of transplanting wheat grass or buffalo grass to treated areas where they are absent. In terms of time, labor, and equipment, trenches or "corrugations" are superior to contour furrows, and in maintaining cover, keeping out weeds, and hastening recovery they possess even greater values.

The study of the relation between cover and wind erosion has disclosed several facts of direct bearing upon the question of the formation of loess deposits. The current view is that the fine material was picked up by the wind during drought in grassland and laid down several hundred miles to the eastward. This theory has been invoked to support the assumption that dust storms have occurred throughout the geological history of the Great Plains and that man in consequence has little responsibility for the recent ones. Through years of field work in the West, dust storms have never been observed to arise from areas with good cover, even during drought periods. Moreover, measurements of the reduction of wind velocity by sparse covers of short-grass render it improbable that dust storms could have come from anything but bare soil. Throughout the "Dust Bowl," the dune ridges have been derived from fields abandoned during drought, and they no longer move when a fair cover is restored. These new facts as to wind erosion and loess deposits were tested in the course of a motor trip to classical loess horizons in Iowa with Dr. Kay and Professor Phillips. As a result, it was agreed that loess had not been derived from grassland but originated from wind erosion on bare glacial outwash plains and valley deposits.

HISTORICAL CLIMATOLOGY

A. E. DOUGLASS

During the past year Dr. W. S. Glock has made detailed study of the relation between ring growth and rainfall in the pine trees near Prescott by correlation and trend coefficients (see Year Book No. 32, 1933). He finds that correlation is strong when the ring growth is compared with the rainfall for the preceding January, February, and April, using unsmoothed data without lag. The month of March introduces erratic results. After the data had been smoothed the best correlation with tree growth was found in the rainfall from November to April, inclusive, with one-year lag. He reports that in smoothed curves it is easy to pick out the correlations visually.

In the summer of 1937 important aid was received from the United States Forest Service. This consisted of maps showing the location of the giant sequoia stumps from which V-cuts have been made, and which have contributed greatly to the study of ring growth. This includes the areas in the vicinity of General Grant National Park, from which collections were made in 1915, 1918, and 1919, and from the old Enterprise Mill site near Springville, California, from which collections were made in 1919, 1925, and 1931. For aid in this matter we are indebted to the United States Forest Service, Washington, D. C., and to Mr. S. B. Show, Regional

Forester in San Francisco, and Mr. J. E. Elliott, Supervisor of the Sequoia National Forest. The stumps were identified by Dr. Glock in a series of field trips on which he was made the guest of the Forest Service.

PUBLICATIONS

Carnegie Institution of Washington Publication No. 486, entitled *Principles and methods of tree ring analysis*, by Dr. W. S. Glock, with a foreword by A. E. Douglass and a contribution by G. A. Pearson, was issued on September 15, 1937. This forms a long-needed introduction to much that has been published already on the subject of tree ring work. A pamphlet entitled *Tree rings and chronology*, by A. E. Douglass, was published by the University of Arizona October 1, 1937, as a Physical Science Bulletin No. 1, and gives a summary of tree ring work. Much attention has been given to the possibility of publication by microfilm. Microfilm copies of volumes I and II, *Climatic cycles and tree growth*, are now available.¹ The photographic part of a fourth volume in the series on *Climatic cycles and tree growth* has been prepared, containing a photographic ring chronology extending back to A.D. '11. These photographs were made by H. F. Davis, and the dating and annotations entered by the writer. It is proposed to make available also in this microfilm form a very large collection of annotated photographs, thereby greatly increasing the number of localities represented in the ring chronology of the last 1900 years.

CYCLIC ANALYSIS

In the Year Book reports for 1936 and 1937 mention has been made of the application of cyclograph analysis to solar rotation studies in the Magnetic Character Figure C and in comparisons between sunspot and calcium flocculus occurrences, and ultraviolet light and other forms of radiation. This has brought to light the service which can be rendered by cyclograph studies upon certain data which have only been examined heretofore by harmonic analysis methods. No better illustration of this could be given than the direct comparison between cyclograph and harmonic analysis of the Magnetic Character Figure C for the years 1932, 1933, and 1934. When minutely compared it is seen at once that the cyclograph, while showing general results (as in harmonic analysis) for the length of solar rotation, shows subordinate results at the same time; for example, in the same pattern we get not only full solar rotation but the half-rotation also, and we see the occurrence of certain phenomena in one solar longitude and the occurrence of similar phenomena in the opposite solar longitude presented toward the earth two weeks later. After these results have been obtained by the cyclograph it has been perfectly easy to verify them fully by plotting the location of observed maxima of the Magnetic Character Figure C on a time scale and then adding the maxima of a fabricated curve based on the hypothesis that the well-known six-months maxima alternate in opposite solar longitudes. The two are found to agree.

¹ Bibliofilm Service, Department of Agriculture, Washington, D. C. See list of Carnegie Institution publications. Volume III of the above series and Dr. Glock's book just referred to are also available in that form.

An addition has now been made to this kind of result by an analysis of radio reception energy recorded by Dr. H. T. Stetson for the same years, 1932, 1933, and 1934. These radio reception data gave a pattern recognized immediately as extremely similar to the pattern of Magnetic Character Figure C. Amplitudes were large and small at the same time. Thus six-months maxima showed in the radio reception as in the Magnetic Character Figure data. When minute details of the patterns were compared it was evident that the relation between these two phenomena was inverted, that is, the reception energy increased with the decrease of the Magnetic Character Figure C. A plot of the radio reception over this period of time compared with a plot of the Magnetic Character Figure verified at once this strong inverse relation.

In connection with these applications of the cyclograph to a field that has been explored extensively by harmonic analysis, the former's great advantage in getting almost instant results visually and its unique facility in showing the time element in changing cyclic conditions have caused us to regard the word "cycloscope" as fully applicable to the instrument. For the sake of clarity the word "cyclic," meaning unstable cycle or discontinuous period, is being tried out elsewhere as a possible alternative for the word cycle.

STAFF

The three-year cooperative arrangement between the Carnegie Institution and the University of Arizona came to a close at the end of 1937. However, Dr. Glock's important work on the ring-rainfall relation at Prescott, and other compilations that he was engaged on, were continued for another half-year. During the last half of 1937 we enjoyed as before the courtesy of the Desert Laboratory of the Carnegie Institution in Tucson. We of the tree ring work express our deep appreciation for the many years of aid from the Carnegie Institution. In the meantime, on December 4, 1937, a Laboratory of Tree Ring Research was established by the Board of Regents at the University of Arizona, where important parts of the tree ring work will be continued.

PALEOBOTANY

RALPH W. CHANEY

Studies of Cenozoic plants have continued along the lines described in previous reports and may be summarized as follows:

R. W. CHANEY. In the spring of 1937, an invitation was received from the National Geological Survey of China to cooperate with members of its staff in a study of a recently discovered fossil flora from Shantung Province. Large collections were examined during the summer in Peiping, and additional material was secured during a short period of field work. Preliminary preparation of the manuscript was carried on in cooperation with Dr. Hsen Hsu Hu, Director of the Fan Memorial Institute of Biology. This flora represents the first record of Miocene vegetation in China. It includes many plants which are represented by related fossil species in the Miocene floras of Siberia, Japan, North America, and Europe. From most of these floras it

differs in its absence of redwoods and other conifers, and in the greater abundance of warm-temperate types, such as figs and laurels. Various conclusions are being reached regarding past migrations of forests in Asia, and the climatic changes which caused them.

Recent collections from the Miocene on the west slope of the Cascade Range in Oregon indicate a close similarity to floras of this age on the east side of the mountains. It is concluded that the Cascades were not raised up until near the close of the Miocene, and that broad valleys or embayments were present along the Oregon coast in which elements of an earlier, less temperate flora survived into this epoch.

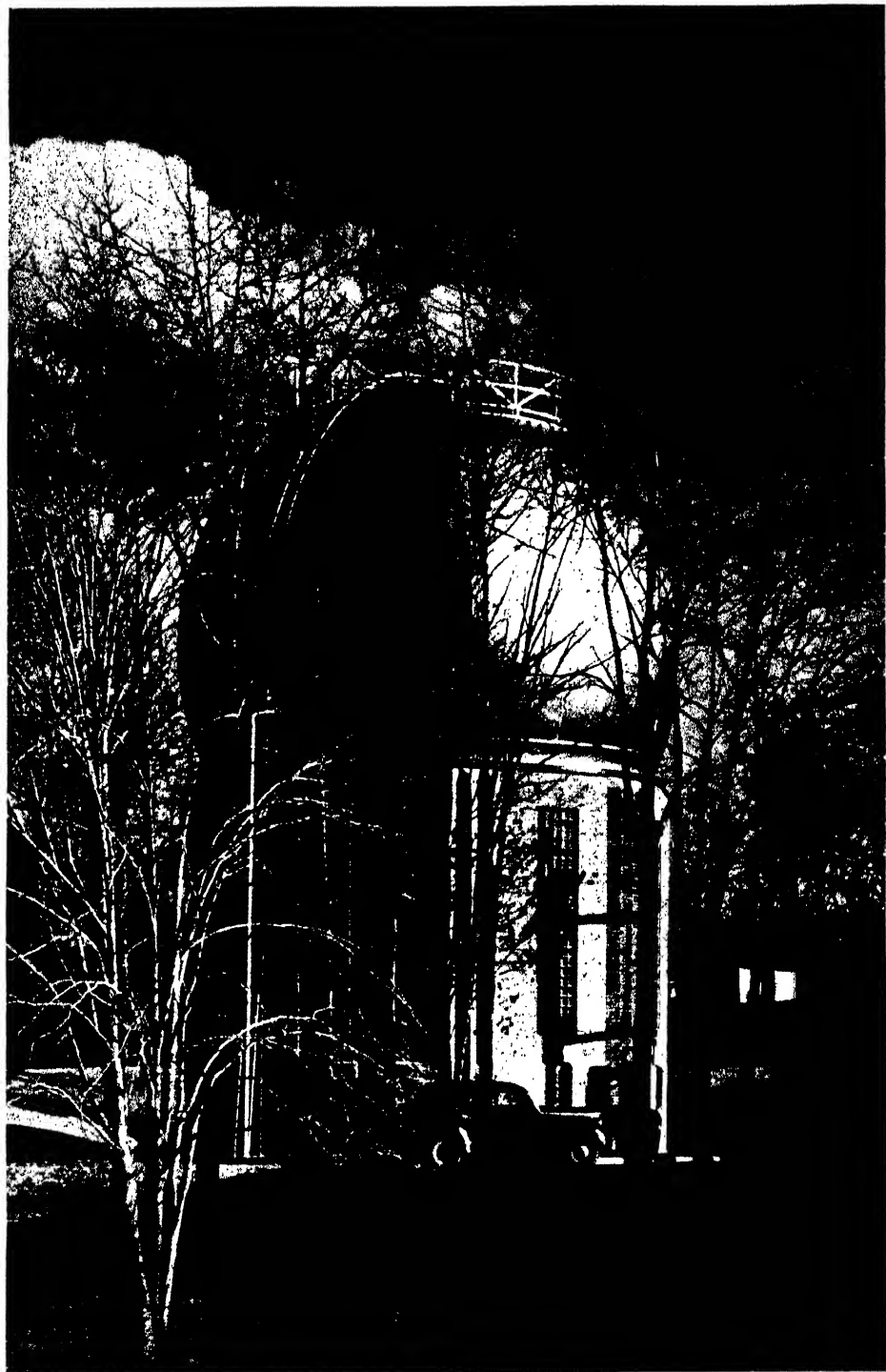
D. I. AXELROD. Further studies of the Miocene and Pliocene floras of California have indicated northward movement of a Mexican element during later Tertiary time. The presence of this element in Tertiary deposits in the western United States may be used as an indication of their late Miocene or Pliocene age.

C. CONDIT. Several floras of Upper Miocene age from central California indicate varied living conditions during this epoch, conditions which have been greatly altered down to the present. A forest of bald cypress (*Taxodium*) occupied the shores of what is now the San Francisco Bay area, while in the hills to the east, the plants indicate a cooler and less humid environment.

E. DORF. The study of a flora of Cretaceous age from the Medicine Bow formation of the Rocky Mountain region has been completed. This flora includes many plants unlike those now living, which is consistent with its occurrence in rocks which were laid down before the modern development of angiosperms. Studies are in progress which will throw further light on the ancestry of Tertiary and modern floras of western America.

R. S. LAMOTTE. A supplement to Knowlton's *Catalogue of the Mesozoic and Cenozoic plants of North America* has been prepared to include publications issued since 1919. In view of the extensive investigations which have been carried on during the past twenty years, particularly in western America, this addition to the catalogue and bibliography will be of great value to all paleobotanists.

H. D. MACGINITIE. A continuation of the study of the Florissant flora by Dr. MacGinitie has resulted in additional collections and the accumulation of significant data regarding conditions of deposition of the volcanic shales in which fossil plants are so abundant. This work has been carried on with further financial support by Mr. Childs Frick, of the American Museum of Natural History. Dr. MacGinitie has also continued his study of the Chalk Bluffs flora on the western foothills of the Sierra Nevada. This represents one of the largest and best-preserved Eocene floras in western America.



THE ATOMIC-PHYSICS OBSERVATORY, DEPARTMENT OF TERRESTRIAL MAGNETISM,
WASHINGTON, D. C.

DEPARTMENT OF TERRESTRIAL MAGNETISM¹

JOHN A. FLEMING, DIRECTOR
O. H. GISH, ASSISTANT DIRECTOR

SUMMARY

The report-year (July 1, 1937 to June 30, 1938) has been marked by energetic prosecution of experimental investigation and continued coordination and integration of various researches paving the way for more general formulation of geophysical facts. Good progress has been made in two major projects which open new fields of investigation and promise important advances. One of these is the completion of the Atomic-Physics Observatory and the considerable progress in the installation of the electrical equipment. The electrostatic generator and tube are designed to operate at potentials exceeding five million volts and offer unique opportunity for further studies in the expanding field of nuclear physics—a field to which we must look for additional understanding of magnetic phenomena. The second project realized is the installation of the automatic multifrequency equipments for ionospheric measurements at both the Huancayo and Watheroo magnetic observatories. This equipment, developed at the Department, has the following characteristics: ability to record successfully without interference from existing radio services; relatively uniform vertical radiation throughout the frequency-range; automatic interlocking of transmitting and receiving tuning; mechanical simplicity and uniform limits of precision and resolution. The stations at Huancayo and Watheroo operating continuously in conjunction with a somewhat similar equipment at the National Bureau of Standards station at Meadows, Maryland, should provide a much more complete survey of the upper atmosphere than has been previously possible. Results at the Kensington Experimental Station of the Department in Maryland, where the apparatus was tested, appear to have gone a long way toward settling the vexed question of the ionosphere and its refractive index for radio waves, an uncertainty heretofore restricting our ability to interpret ionospheric observations.

Magnetic investigations. The outstanding advances in magnetic investigations concern two distinct branches of the science: the rapidly varying external field and the slowly varying, so-called permanent field. A procedure was developed for separating the internal and external portions of a localized varying magnetic field observed at the Earth's surface without recourse to the use of spherical harmonics by assuming the Earth's surface to be an infinite plane and employing solutions of Laplace's equation appropriate to the case. This permits the hypothetical mapping of the magnetic field at various heights, from which cogent inferences may be drawn regarding the location of the processes giving rise to the magnetic effects. Further attention was devoted to the theory suggested in 1936 to account for auroral-zone features of magnetic disturbance and for the average characteristics of magnetic storms in polar regions.

¹ Address: 5241 Broad Branch Road Northwest, Washington, District of Columbia.

Measurements made on a sample of sediment extending 9 feet into the floor of the North Atlantic Ocean show marked differences in the magnetization at various depths. If correctly interpreted, these measurements indicate that the direction of the compass in that region was about 60° east of true north at the time the sediment was deposited many thousands of years ago, whereas at the present time in the same locality it is 30° west of true north. In further investigations of this nature, varved Pleistocene clay from beds of old glacial lakes near New Haven, Connecticut, was collected for like examination. This method of studying geomagnetism through the measurement of fossil magnetization holds the hope of possible determination of secular changes in geologic ages. A method of measuring the moment of small magnetic dipoles was devised in this connection. The theoretical sensitivity and practical application are such that moments of 3×10^{-7} CGS unit can be detected. Consideration was given to methods of interpreting geological structures from their effects on the Earth's magnetic field as observed at the surface, particularly for application in volcanic regions.

The weekly American magnetic character-figures (C_A) for the seven American-operated observatories at Watheroo, Huancayo, Cheltenham, Honolulu, San Juan, Sitka, and Tucson were compiled and published regularly each week through *Science Service*. Statistical examination of the data for the first year of this character-figure shows it to be a precise measure and to represent worldwide conditions with relatively high fidelity. The first six months of 1937 reveal a close relation to the international magnetic character-figure adopted from the records of over forty observatories. It appears that, while the international figure is superior for selecting extremely quiet days, the American figure is superior for selecting extremely disturbed days and for the study of radio-communication conditions. Studies of the effect of magnetic activity on radio-transmission conditions showed the two phenomena to be closely correlated, superior results being obtained by use of the American magnetic character-figure.

Cosmic radiation. The investigation of a positive relationship of cosmic radiation with magnetic and other phenomena was continued. Worldwide decreases of 3 to 5 per cent in daily means of cosmic-ray intensity are found to be associated with changes in the Earth's magnetic field during two major magnetic storms; other magnetic storms of equal intensity occur with no appreciable cosmic-ray effects. Thus it appears that the entire current-system for the storm-time field of both types of storms cannot be located at the same distance above the Earth. A significant correlation between changes in daily means of cosmic-ray intensity for two stations separated 50° in latitude probably results from the mechanism responsible for the magnetic-storm effect. Statistical analyses of the cosmic-ray records obtained at Cheltenham and at Huancayo proved inadequate to establish a sidereal diurnal variation in cosmic-ray intensity.

Analysis of all available data from Cheltenham, Teoloyucan, Christchurch, and Huancayo shows that the major changes in the 10-day means of cosmic radiation are all worldwide. The correlation between the worldwide changes at different stations was found high enough to provide important information regarding their variation with latitude and altitude. It seems impos-

sible to explain the annual waves found at these stations in terms of a solar magnetic moment.

Terrestrial electricity. The rationale of the subject, atmospheric electricity, was improved in several respects. For example, the observation that the electrical conductivity of air at sea is relatively independent of latitude was accounted for quantitatively. The quantitative dependence of air-conductivity upon the intensity of cosmic radiation up to considerable altitudes, especially over the oceans and the polar regions, was more securely established. The electrical resistance of a vertical column of atmosphere, as calculated from the observed intensity of cosmic radiation, was found to be about 20 per cent greater at the equator than at 50° latitude. This provides an acceptable explanation for the dependence of electric field-strength upon latitude, which was shown by observations made on cruises of the *Carnegie*.

It was found that condensation-nuclei (ultramicroscopic aggregates of molecules upon which water-vapor readily condenses) are formed in air in the laboratory by ultraviolet light. This observation strengthens the likelihood that the stratum of nuclei—which was indicated by registrations of the electrical conductivity of air, made on the stratosphere flight of the balloon *Explorer II*, at an altitude of 18 to 22 km—is formed in this way, and that the apparent association of nuclei and ozone is significant.

Observations of the apparent reflection of radio waves from relatively low levels in the troposphere and stratosphere have been interpreted by some investigators as evidence of very intense ionization at these levels. This interpretation was shown to be inadmissible; the ionization observed in these regions is nine orders of magnitude less than that implied by that interpretation, and the energy required to maintain extensive layers of that character is not available.

It was shown by an analysis of registrations of the electric currents in the Earth at Tucson, Arizona, and at Huancayo, Peru, that the Moon exercises a secondary influence on those currents, giving rise to a harmonic component in the daily variation which has a period of 12 hours and an amplitude about one-fifth to one-sixth that of the variation which follows solar time.

Ionosphere. Isolation of the radio fade-out effect in a particular region of the ionosphere was accomplished using the powerful automatic multi-frequency technique. The ionization in the outer atmosphere produced by the ultraviolet light emanating from the bright chromospheric eruptions is absorbed almost exclusively below the level of about 90 km. This constitutes strong confirmatory evidence that the electrical currents causing the diurnal variation in the Earth's magnetism must flow below this level. That the ultraviolet radiation from the bright eruptions on the Sun is not absorbed in the higher regions of the outer atmosphere in passing through them is new evidence of the physical constitution of these regions, and of the processes producing ionization in them. This provides a new approach to the study of physical problems of the outer atmosphere and of the Sun.

Continual recording of the electrical state of the outer atmosphere is now an accomplished fact at the magnetic observatories of the Department at Huancayo and at Watheroo. Installation of the automatic multifrequency

equipment represents the culmination of a long period of research and development by the Department to make possible a complete record of ionospheric fluctuations. Thus the ionosphere—the region of transition in which many solar effects are translated into observed geophysical phenomena—is now under continuous observation.

The experimental determination of the Lorentz polarization correction in the ionosphere represents a major contribution to the field of classical physics. The relation between the constitution of a conducting medium and its refractive index is a fundamental problem of physics to which attention has been devoted for many years. Heretofore, no experimental determination of this correction had been made, so that the experiments in the ionosphere represent the first factual evidence which has been brought to bear on the subject.

Nuclear physics. Studies in the laboratory of the primary particles of matter, which have magnetic properties as one of their very few attributes, were directed chiefly toward accurate measurements of the large attractive forces which operate inside the nuclei of all atoms. The Department's pioneer measurements two years ago on these nuclear forces, which are neither gravitational nor electromagnetic, but something "new," were amply confirmed here and elsewhere, and are accepted as fundamental to any understanding of the nature of matter and the primary physical forces. The observations of this year, made with a different apparatus and completely independent of the earlier series, served to calibrate all the measurements on an absolute scale (centimeters, grams, seconds) as required for theoretical interpretation and universal applicability.

Instruments. The coil of the new primary standard for measuring in absolute units the Earth's vector magnetic field was completed. It is constructed with an accuracy such that the magnetic field is calculated to about one part in a million. The alidade and mountings for the coil are now under way.

Observatory-work. The observatories at Huancayo, Peru, and at Watheroo, Western Australia, continued the extensive geophysical program, obtaining continuous records of magnetic elements. Magnetic activity was very marked as the peak of the sunspot-cycle was reached during 1937. The remarkable range of 1350 gammas occurred in horizontal intensity during the exceptionally violent magnetic storm of April 16, 1938, at Huancayo.

Cooperative work was continued with the following observatories: Atmospheric-electric program at Apia in Western Samoa; atmospheric-electric and earth-current programs at Tucson, Arizona; maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. Some cooperation was extended to the Magnetic Observatory at Cape Town through the loan of instruments and information regarding methods. As a result of cooperation with the MacGregor Arctic Expedition, a temporary magnetic observatory was established in September 1937 near Reindeer Point at Etah, Greenland.

Land-work. Field work in Australasia and the Pacific Islands was continued. Comparisons of observatory-standards were made at the Apia, Honolulu, Watheroo, and Batavia observatories, and at Blacktown in Australia (with the instruments of the Aerial, Geological, and Geophysical

Survey of Northern Australia). Thirty-five stations were occupied in New Caledonia, New Hebrides, Tahiti, Western Australia, Northern Australia, Malaya, Siam, and French Indo-China. In cooperation with the Gulf Research and Development Company, results at six stations in Arabia were obtained.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM

Those more especially taking part in work reported under terrestrial magnetism include Berkner, Fleming, Forbush, Johnson, Johnston, Ledig, McNish, Torreson, and Vestine. Dr. J. Bartels (in residence at Washington July 23 to September 28, 1937) and Professor S. Chapman, research associates, through constructive advice and their respective researches at London and Berlin, took important part in the year's work.

PERMANENT FIELD

Heights of electric currents near the auroral zone. A mathematical method for separating the internal and external portions of a local magnetic field was developed. Incidentally, the solution leads to inferences regarding the height and form of the origin of the magnetic field.

Assuming the Earth to be an infinite plane, variations in potential may be represented by the equation

$$W = F_e(x,y,z) + F_i(x,y,z)$$

for all points in and close to the plane, the subscripts e and i referring to portions due to origins above and beneath the surface, respectively. Appropriate series-solutions of Laplace's equation are selected to represent the potential, subject to the condition that $F_e(x,y,z)$ vanish at $z = -\infty$ and $F_i(x,y,z)$ vanish at $z = +\infty$, the same functions being used for both the external and internal portions. Appropriate derivatives of W are the components of magnetic intensity. The coefficients of the two potential-functions, external and internal, are additive in the differentiation with respect to x and y but they are subtractive in the differentiation with respect to z , owing to the imposed condition regarding vanishment. As in the theory of Gauss, parameters in series selected to fit the variations in horizontal intensity are sums of the external and internal coefficients, while those for the variations in vertical intensity are their differences. The external and internal coefficients may then be determined by solving pairs of simultaneous equations.

The external and internal portions may be evaluated at various levels above or below the plane where the field is observed, which evaluation is valid provided it is not conducted for a level equal to or above that at which the magnetic field originates. With increasing distance from the plane higher-order terms in the potential-series assume increasing importance so that at some level convergence of the series becomes very poor. This level is taken to be the upper limit for the location of the origin of the potential.

Application of the method to a particular magnetic disturbance indicated

it was due primarily to a flow of current westward along the auroral zone in a sheet about 700 km wide located at a height between 100 and 150 km, the currents induced within the Earth being found comparatively unimportant. Previous estimates for similar currents indicated wide ranges of heights varying between 100 and over 1000 km.

Electromagnetic measurement of rock-magnetization. Numerous measurements and important improvements in method were made to determine the magnetization of rocks. The equipment described in last year's report is now adequately sensitive to meet expected requirements. Measurements made on several of the cores taken from the North Atlantic by Dr. C. S. Piggot of the Geophysical Laboratory gave encouraging indications. Tests on the Pleistocene varved clays from glacial lakes in New England show it is worth while to study them magnetically. Continuation of these researches promises results of fundamental importance to terrestrial magnetism and geology. So far all evidence suggests that sedimentary deposits retain the magnetization which was imparted to them by the Earth's magnetic field, presumably at the time of their deposition. Conclusive information on this point will be secured from tests on collected samples of varved clays. If these tests are affirmative, then a means is afforded for tracing changes in the Earth's magnetism back through geologic ages as accurately as the rocks are dated, and a new means of dating geological specimens, namely by their magnetization, may be available.

For tests the specimen is clamped to a disk of wood mounted on a vertical shaft and is rotated at a speed of ten revolutions per second in a coil wound on a bakelite form mounted in an aluminum box to shield from stray fields. Electromotive forces induced in the coil by the rotating specimen are amplified and rectified by a synchronous commutator geared to the driving shaft and then measured by a sensitive galvanometer. By rotating the brushes on the commutator so that a zero-reading is obtained the direction of magnetization may be determined, while the intensity of magnetization is determined by the maximum deflection. A small test-magnet mounted in a bakelite block is used for calibration. Effects produced by vibration of the coil in the Earth's field are eliminated by having a second layer on the coil wound in the reverse direction. The theoretical limiting sensitivity of the apparatus is the detection of an intensity of magnetization of 8×10^{-8} CGS in a cubical specimen 15 mm on each edge, although practical limitations are set by finding material for the rotating mechanism which is less magnetic than the specimen to be tested.

Extensive tests were made on several cores taken from bottom-deposits of the North Atlantic by Dr. C. S. Piggot of the Geophysical Laboratory. Core no. 3, taken off Newfoundland, consists of a finely divided material known as blue mud. Changes in magnetic declination as great as 90° and consistent through the core were measured. If these changes correspond to real changes in the Earth's magnetic field they exceed any which have been recorded in historic times, although they are not so great as to cast doubt on their reality. Changes as great as 36° in declination have been recorded at London during two centuries. It has been estimated that this particular core represents sediments deposited over several thousands of years.

Tests made upon two cores taken within about 100 miles of each other in the middle of the Atlantic gave inconclusive results. They contained many pebbles, so that satisfactory specimens could not be cut from them. Existence of these pebbles, which were too large to be aligned by the Earth's field as they settled upon the bottom, would give rise to erratic directions of magnetization such as were observed. Portions of these cores which were sufficiently homogeneous to permit fairly reliable measurements gave fairly concordant results. Core no. 13, taken near the coast of Ireland, could not be tested because of the extreme friability of the material and presence of pebbles.

Measurements were made on a sample of varved Pleistocene clay from old glacial lakes near New Haven and showed this clay sufficiently magnetic to permit analysis. Therefore some 200 varves were collected in June 1938 from the same region for detailed examination. These samples were collected in brass troughs with great care following the method employed by Antevs in developing the chronology of the deposits, and with definite reference to the geographical and prevailing magnetic directions.

Interpretation of geologic structures from anomalies in terrestrial magnetism. Methods for interpreting geologic structures from magnetic anomalies produced by them at the Earth's surface were investigated. Conventional methods were extended and more powerful techniques considered. These were tried on several hypothetical cases and gave remarkably decisive results. The methods were developed particularly for application in volcanic regions.

Map of secular variation. A world-map of secular-variation activity was constructed for the interval 1885 to 1922. It differs from others in that it shows isopors for the magnitude of the total-change vector, regardless of sign or direction. Most maps show secular change in only one element or several elements superposed, and since secular change in vertical intensity must have a minimum where secular change in horizontal intensity or declination has a maximum, interpretation of the maps is difficult. This map shows again the fact brought out by Fisk that most secular-change activity occurs in that portion of the Earth which is assumed to have a granitic crustal layer; the Pacific Ocean is remarkably free from secular-change activity.

COSMIC RELATIONS

Solar and terrestrial relationships. The report-year has been of unusual interest for the study of solar and terrestrial relationships, and of the relations between terrestrial magnetism and other phenomena, such as cosmic radiation. In a steep increase since the last sunspot-minimum of 1933.8, solar activity, as expressed by the relative sunspot-numbers, reached 114 in the annual mean for 1937, a value which exceeds considerably any-annual mean since the high sunspot-maximum of 1870. The intensity of magnetic disturbance followed this increase, and the year 1937 appears to be the most active year for over 60 years, although no individual storm of outstanding intensity occurred in 1937. But January 1938 was marked by three successive storms. A violent magnetic storm of exceptional character on April 16, 1938, was preceded 21 hours before by an exceptional eruption observed

on the Sun's surface. Because of the well-known lag of magnetic behind solar activity, it is quite likely that the lull of magnetic disturbance experienced in June 1938 will be only temporary, and that the harvest of magnetic storms for the study of their general features, their individualities, and their variable effects on the ionosphere and cosmic radiation will increase in the next year.

In conjunction with a research student, A. J. Majid Mian, Chapman is attempting to express the daily variation of monochromatic ion-production and ion-content in the atmosphere, in terms of a Fourier series, and, further, to express the geographical distribution of these quantities in terms of spherical harmonics; some progress is being made in this rather difficult investigation which should assist in future attempts to perfect the theory of the daily magnetic variations.

Geophysical lunar almanac. The investigation of solar and lunar effects is recognized as a major approach in the discussion of geophysical phenomena. But apart from the well-known case of the oceanic tides, lunar influences have been studied by comparatively few, although the large-scale experiments performed daily by the Moon on the Earth are so much simpler in character—purely gravitational—than those performed by the Sun. This is largely because the magnitude of the lunar effects, with notable exceptions, is usually only a very small percentage of the total variability, so that much observational material must be used and a special statistical technique must be developed to obtain reliable results.

Investigators in this field have keenly felt the lack of auxiliary tables giving the motion of the mean Moon in a manner suitable for geophysical work; thus, many calculations have been based on the convenient data for the apparent Moon, furnished by the astronomical yearbooks. This expedient has, however, the serious drawback that the connection is lost with the harmonic analysis of the tidal force which is an adequate description for that complicated time-function and is based on the mean Moon; furthermore, the unequal length of the apparent lunar day is troublesome in the calculation. For this reason, the geophysical lunar almanac was prepared by Bartels with the collaboration of G. Fanslau; it gives, for each day from 1850 to 1975, the phase of the mean Moon, its distance from mean perigee, and the mean ascending node of the Moon's orbit. It is hoped that this almanac will help to establish more uniformity in lunar geophysical work.

The work supervised by Chapman in the computing bureau on lunar variations in magnetic and barometric data went on actively and some progress was made in preparing for publication.

Cosmic-radiation relations. Recent investigations of the data from cosmic-ray meters at Cheltenham, United States, Teoloyucan, Mexico, Christchurch, New Zealand, and Huancayo, Peru (the last practically on the magnetic equator) have shown that after a 12-month wave is removed from the data at each of these stations except Huancayo, which shows none, the means of cosmic-ray intensity for each one-third month are remarkably similar at all stations. The high correlation between these worldwide changes in cosmic-ray intensity at any two stations is exceeded by few, if any, geophysical phenomena measured at such widely separated stations. The char-

acter of these worldwide changes is such as to suggest the continual existence of equatorial ring-currents with changes in intensity or radius. This supposition is strengthened by a strong 27-day recurrence-tendency in the cosmic-ray data. The variation of magnitude of the worldwide effect in cosmic-ray intensity with altitude and latitude indicates that the continued existence of ring-currents may have important consequences in the interpretation of the latitude-variation of intensity at extreme altitudes. A quantitative theory for the explanation of the worldwide changes in cosmic-ray intensity may also be expected to disclose the fundamental mechanism causing magnetic storms. The quantitative results of cosmic-ray investigations provide excellent material for checking a quantitative theory for the worldwide effect.

MAGNETIC DISTURBANCES

Average worldwide changes during magnetic storms. The average worldwide changes in the Earth's field during magnetic storms, additional to those present on magnetically quiet days, were investigated using extensive new data of the International Polar Year, 1932-1933, in continuation of a study undertaken under the supervision of Chapman. The average characteristics of disturbances given by observation were shown to be in good qualitative and quantitative agreement with the worldwide atmospheric-electric current-system of magnetic storms proposed by Chapman. If these electric currents flow in closed circuits in the atmosphere their height is deduced as roughly 100-150 km. The electric current-system proposed by Birkeland was shown to be inconsistent with observation in several important respects. In low latitudes of the Earth it is also possible that the storm-time variation is due mainly to an encircling ring-current in the equatorial plane, in which case its radius computed from the magnetic data was found to be about two to four times that of the Earth.

Average characteristics of magnetic storms asymmetrical relative to the centered dipole of the Earth's magnetic field. This investigation is a sequel of the foregoing. Since magnetic disturbances appear with highest intensity in the region very near the auroral zone, the magnetic data were used to give a new and improved determination of the geographical position of this zone. The auroral-zone curve of terrestrial magnetism, in north polar regions, is oval, almost elliptical, and shows asymmetry relative to the centered dipole. It agrees roughly with the curve of maximum auroral frequency as derived by Fritz, except in regions where his auroral data were scanty.

The average disturbance diurnal variation of magnetic storms is mainly sinusoidal in character. Little or no significant dependence of the amplitude of the disturbance diurnal variation upon longitude was found. The amplitude is approximately symmetrical about the geographic equator, is zonal-symmetrical with respect to the auroral zone, and has a zero vertical component near the north pole given by the eccentric dipole most closely representing the Earth's field. Induced electric currents flowing in the oceans appear to contribute little to the diurnal variation. In general, the local time-phase of the variation shows an average range of about four hours along parallels of geomagnetic latitude. The time-phase depends closely upon the magnetic time (referred to the north pole given by the eccentric dipole) for

intense disturbances appearing at the auroral zone. This suggests that the electric currents causing this diurnal variation are generated near the auroral zone, and an investigation is under way to determine whether currents initiated in this way would give rise to an electric current-system compatible with observation. The asymmetrical characteristics of magnetic disturbance are also compared with those shown by aurora.

Origin of magnetic disturbance in polar regions. It is believed that most of the phenomena can be accounted for by means of a dynamo-theory similar to that proposed by Chapman in 1918 and subsequently extended in 1936 at this Department to account for magnetic "bays." A brief outline of the present trend of this theory follows: Impact of corpuscles, giving rise to auroral phenomena, along the auroral zone in the region between midnight and dawn causes expansion of the upper atmosphere and consequent generation of electromotive forces through vertical motion of atmosphere across the horizontal component of the Earth's permanent field. This gives rise to a westward current along the auroral zone which closes through low latitudes and across the polar cap. A collapse of the expanded atmosphere on the opposite side of the auroral zone causes eastward currents in a similar manner with corresponding closures.

During the past year V. C. A. Ferraro renewed his cooperation with Chapman in the attempt to construct a deductive theory of magnetic storms and auroras by developing and improving the theory they published some years ago. Progress in this work strengthens the hope that this theory is on generally right lines.

MAGNETIC ACTIVITY

Bartels computed the final u -measure of magnetic activity 1935 and 1936, and preliminary values through April 1938. Three storms in January 1938 gave the high value $u = 2.74$, while the annual mean for 1937 reached 1.38; this exceeds the highest annual values of u reached during the last five sunspot-maxima (1.18 in 1926, 1.23 in 1919, 0.98 in 1909, 1.33 in 1892, 1.22 in 1882). This variable intensity of the maxima in the 11-year cycle has a counterpart in the different degree of terrestrial-magnetic quietness reached during the sunspot-minima. Since the last-mentioned differences appear more marked in the magnetic data than in the relative sunspot-numbers—the minima of 1901 and 1913 were appreciably quieter in magnetic respect than those of 1923 and 1933—a special study was made to ascertain whether these differences were real and not due to some fault in the measure of activity. It appeared that the magnetic evidence is conclusive, and that it is in conformity with solar observations in so far as the Sun was entirely free of spots on more days around 1901 and 1913 than around 1923 and 1933.

Character-numbers for magnetic disturbances. In connection with the various proposals for the adequate description of magnetic disturbances, Bartels formulated a Potsdam Magnetic "Kennziffer" (K). Its main difference from existing international and American (C_A) character-figures is the division of the Greenwich day into eight intervals of three hours each. Such a shorter interval seems more suitable because of the difficulty experienced in ascribing a single figure to a day or a half-day in which the degree of dis-

turbance may vary considerably; on the other hand, a further subdivision (hourly intervals) would add greatly to the labor involved without proportional gain to justify it. *K* consists of two figures; the first, varying from 0 to 9, indicates the highest amplitude in the deviations of one of the three magnetic-force components from a smooth diurnal variation, while the second indicates the form of the variations (pulsations, bays, storms). So far, the definition of *K* has been chosen so as to give a good characterization of the records of Niemegk Observatory; the experience gained there should advance discussions for an international code.

ARCHIVES OF MAGNETIC RECORDS

Polar-Year magnetic records. The Department now has on file most of the special records made during the Second International Polar Year. Nearly 1000 miniature film-records have been received from the Central Bureau of the Polar Year Commission at Copenhagen, Denmark. Each film gives one month of daily records from one observatory. A special apparatus was purchased to permit rapid and accurate reduction of these records for special investigation.

Solar photographs and sunspot-charts. The United States Naval Observatory supplies the Department prints of its daily solar photographs for use in studying and anticipating magnetic disturbances. In several cases these have permitted forecasts of magnetic disturbances so that the Department was able to supply information whenever requested by persons engaged in radio work or cosmic-ray research. These photographs are supplemented by carbon copies of the charts of sunspots made daily at the Mount Wilson Observatory, which are received some time later.

INSTRUMENTAL DEVELOPMENTS

CIW induction-variometer. The CIW induction-variometer for measuring time-variations in the vertical component of the Earth's magnetic field was kept in continuous operation by the staff of the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. During its last period of operation extending over two years no sudden changes in base-line or sensitivity have occurred such as are common to most instruments of the "knife-edge" pattern. Despite excessive ranges of several severe magnetic storms, the variometer returned to normal values without any evidence of having been affected. Base-line drift, which was rather great when the instrument was first installed, has diminished continually. Experience thus proves the practicality and superiority of this instrument for use at observatories.

Electromagnetic methods. Johnson continued the design and construction of the coil-form of the new CIW primary standard for measuring the Earth's magnetic vector (see Year Book No. 36, pp. 11-13). The actual construction of the coil, the most difficult part of the standard, is now completed. The grooves in the pyrex coil-form were ground by means of a cast-iron lap and fine emery, using optical methods of grinding, in a room kept at a constant temperature of 26° C and 100 per cent humidity during grinding to

avoid variations caused by temperature and by evaporation. To measure the diameters along the coil a mechanically operated micrometer was built, in which the time of contact is signaled electrically; its sensitivity is greater than 0.1 micron. Measurements on the diameter of coil were made to ± 0.25 micron. The measurements on the coil itself show that it is cylindrical to ± 0.5 micron or better, and uniform along the axis of the cylinder to ± 1 micron or better.

The wire used in winding the coil is uniform to a few tenths of a micron and was wound on the coil with uniform tension. A test of the uniformity shows that the wires in place on the coil-form are all uniform to within about ± 0.5 micron.

The method of measuring small magnetic moments was fully developed during the year and was applied to the measurement of the polarization of sedimentary deposits from the bottom of the Atlantic collected by Dr. Pigot of the Geophysical Laboratory.

In connection with the development of the alternating-current voltage-measurements from the rotating coil of the primary standard, the limitation of alternating-current voltage-measurements due to a statistical source in the circuit in which a signal-voltage is to be measured was calculated theoretically and was determined experimentally. It was found that the limit of measurement was not dependent on the band-width of the amplifier, as has been previously supposed, but depends only on the time of measurement and the amount of the statistical voltage. From the analysis it becomes evident that for a given circuit the use of alternating-current amplification yields no theoretical increase in sensitivity over direct-current methods of measurement, although in many particular problems alternating-current methods offer great advantages. This result has been applied in the case of the measurement of small magnetic moments as well as to the case of the primary standard. The analysis also applies in the case of the searchlight-experiment and has numerous other practical applications of general interest.

Some preliminary experiments were made with a flickering searchlight-beam for investigating the upper air by Johnson, Meyer, and Tuve in collaboration with O. R. Wulf of the Fixed Nitrogen Laboratory. Although the experiments were not conclusive, the light scattered from low heights was measured and the method was shown to be practical. Chapman in England in conjunction with A. Hammad made some progress in the study of secondary scattering of light in the atmosphere.

PUBLICATIONS

The bibliography given below lists the Department's communications on geomagnetic investigations during the year. At the suggestion of Chapman, his colleague A. T. Price is preparing a book on electromagnetic induction with geophysical and electrotechnical applications; it is hoped to include in it an account of the work, mentioned in last year's report, by M. A. El Wakil, on Rolf geomagnetic pulsations and their primary and induced current-systems.

TERRESTRIAL ELECTRICITY

The electric phenomena and properties of the atmosphere (atmospheric electricity) and those of the Earth (geoelectricity) are comprised in the subject of terrestrial electricity. Investigations of one or more aspects of these subjects were pursued at Washington during the year by the following persons: Gish, Mauchly (temporary assistant, June 28 to September 15, 1937), Rooney, Sherman, Torreson, and Wait, and Dr. R. Gunn as research associate from May 3, 1938.

ATMOSPHERIC ELECTRICITY

Investigations in atmospheric electricity, although often of interest in themselves, are largely directed toward a search for the mechanism by which negative electricity is supplied to the Earth at an average rate of about 1800 amperes for the whole Earth. The source of this supply-current has thus far escaped definite detection, but study of the current of positive electricity, which flows from air to Earth in all areas where fair weather prevails and which can be measured, leads to the foregoing estimate of the supply-current magnitude and shows that it undergoes a fairly regular variation during the day. Whether and in what manner it varies during the year and from year to year is not clearly established, except that such variations, if existent, are largely of the nature of oscillations about some mean value. Perhaps the supply-current is generated in areas of storm, but, because of the great obstacles to the making of suitable measurements there, this surmise has not been adequately tested by direct observation of the current in such areas. It is rather studies of the electric current in areas of fair weather which thus far have provided most information regarding the supply-current. These consist in measurements of the electric field and of the electrical conductivity of the air. Most of the investigations of the report-year pertain to agencies which affect the conductivity and thereby give rise to variations from time to time and from place to place in the electric conduction-current from air to Earth in areas of fair weather. These investigations are outlined more specifically in the following paragraphs.

Ion-forming and ion-destroying agencies. The concentration of the ions, upon which the conductivity of the air depends, is determined by the rate of formation, the rate of destruction or transformation, and the migration of ions. Wait and Torreson continued the continuous registration of large, intermediate, and small ions, and the rate at which ions are formed in a very thin-walled vessel at Washington. This was done in a well-ventilated room of the absolute observatory until December 30, 1937, and thereafter in a sealed room of the main building using two ionization-apparatuses. In conjunction with these registrations, manual observations of the concentration of Aitken nuclei, from which large ions are formed, were also made. In the sealed room the contribution of nuclei and large ions from the human breath was further studied.

Examination of the records obtained in the sealed room showed that the large-ion and small-ion content of the air in the room responded to occupancy in a manner similar to that found from earlier work. In addition, and of particular interest, was the discovery that the ion-production as represented

by the measurements with the thin-walled chamber also shows response to occupancy, the ionization being smaller when the building is occupied than when it is vacant. This result is not explainable from our present knowledge of the subject, and requires further investigation.

In November and December 1937, while ionization-apparatus 1 retained its thin wall of cellophane, the wall of apparatus 2 was thickened by coating the cellophane wall with paraffin. From the different results obtained under these different conditions of operation it was possible to derive the amounts of ionization contributed by the different types of radioactive radiations, cosmic radiation, and residual or wall ionization.

In May and June 1938, the ion-counters were used for various tests bearing on the question as to whether or not ions are produced when ozone is exposed to light of short wave-lengths. The study of ionization of ozone is one line of attack on the problem of how those radio fade-outs which accompany solar eruptions are produced. Radio fade-outs accompanying bright chromospheric eruptions on the Sun appear to be due to increased ionization in the upper atmosphere at levels between 60 and 100 km, *below* the E -, F_1 -, and F_2 -regions of the ionosphere. It seems necessary to explain the increased ionization between 60 and 100 km through the absorption of solar radiation by some constituent of the atmosphere that does not exist at the higher levels of the recognized ionospheric regions. It appears possible that ozone, which is present in the region between 60 and 100 km, may be decomposed through the absorption of radiations which lie in the range of 2800 to 2200 Å, and that through the process of decomposition ionization occurs. This would afford a simple explanation of fade-out ionization which accompanies bright chromospheric eruptions. To what extent ionization does accompany decomposition of ozone can be determined through experiments in the laboratory, and preliminary tests relating to this matter were made by Wait and Torreson with ion-counting apparatus in the sealed room.

In these tests, a mercury-arc quartz lamp was operated in the room. The results show that when the mercury-arc lamp is operated, a large number of large ions appears and, when the lamp is cut off, these large ions disappear only gradually from the atmosphere, requiring a period of several hours to do so. Small molecular ions must also be produced in enormous quantities, but the small-ion counter shows only a moderate increase in number since the small ions can persist only an extremely short time before they either are caught by the great number of large ions already present or themselves grow into large ions. Certain of the tests with the mercury-arc lamp showed that the large ions result from the action of the radiations from the lamp on some as yet undetermined material in or of the atmosphere, and are not particles given off directly by the lamp itself. Tests were next made with the mercury-arc lamp replaced by ionium as the ionizer, the ionium being placed at the intake of the counters. It was found that the small molecular ions produced in considerable quantities by the ionium did not grow in their progress through the ion-counting apparatus; neither the intermediate-ion nor the large-ion content showed any increase during the periods (some of half an hour or more duration) when ionium was used as the ionizer. Experiments are now in progress to determine if the small molecular ions

produced by the mercury-arc lamp grow into large ions, and might thus account for the numerous large ions which always come into existence a fraction of a second after the lamp is put into operation. Information on this point is an important requirement toward the solution of the main problem.

Experiments to test more thoroughly the reliability and characteristics of apparatuses used for the measurement of air-conductivity and of the concentration of small ions were made by Sherman. These verified previous conclusions, based on less exhaustive tests, namely, that the conductivity-apparatus, as generally used in the work of the Department, yields accurate results and that the values measured with the ion-counting apparatus require a correction when intermediate ions are present in sufficient concentration. The only unexpected result of these experiments was that quite appreciable errors in the ion-count may be produced when the observer sits at the instrument throughout the time required for a measurement. This is due to the great number of nuclei and large ions which are introduced into the air from the breath of the observer. A very gentle breeze is, however, sufficient, when properly directed, to obviate this source of error.

The expressions which have been deduced for the relations between the ion-forming and ion-destroying or ion-transforming processes have been reported to be in disagreement with the facts in some cases. Several of these cases were examined by Gish, who found that, by a suitable adjustment of the coefficients in the expressions, agreement is obtained. This and other considerations indicate that the coefficients which have been previously employed are not generally applicable.

The observations of nuclei made at 8^h each day at Huancayo, and studied by Torreson during the year, provided a clue which, together with meteorological and other data, enabled Gish to devise a satisfactory explanation of the remarkable contrast between day and night in air-conductivity and electric field-strength observed at Huancayo, Peru, especially during the dry season (May to September, inclusive). At night, conductivity there is quite large and potential-gradient small, but within nearly an hour centering at about 7^h the conductivity suddenly decreases to one-fourth or one-fifth the night-time values while potential-gradient increases in a corresponding manner. The change in the evening from day to night conditions is more gradual. Meteorological observations indicate that a shallow surface-stratum of air develops at night. The concentration of nuclei in this stratum is doubtless relatively small because in its stable condition there is little mixing with the overrunning general circulation which brings the nuclei from a distant source. To test this explanation, measurements of the concentration of nuclei at night as well as in daytime are required.

Ionic concentration and air-conductivity in the troposphere and stratosphere. Measurements of air-conductivity in the free atmosphere to an altitude of 22 km, made on the flight of the stratosphere balloon *Explorer II*, when compared with measurements of cosmic radiation led Gish and Sherman to conclude (see annual report for 1935-36) that the coefficient of recombination between small ions varies directly as the pressure to the one-third power, instead of the first power as usually assumed. Investigation of the variation of that coefficient with pressure for ions in oxygen, made by

Gardner in Loeb's laboratory at the University of California and reported during the past year, seem to support that conclusion for the range of pressures encountered on the balloon flight. This strengthened confidence in calculations of conductivity from observations of cosmic-ray intensity. It accordingly seemed worth while to make such calculations for different latitudes since the cosmic-ray intensity at the surface depends somewhat upon latitude but more especially because the variation with altitude shows a pronounced dependence upon latitude. The calculations made by Gish and Sherman indicate that the conductivity at the surface over the oceans, where ions are produced almost exclusively by cosmic radiation, is on the average nearly independent of latitude, the higher temperatures at the low latitudes practically counteracting the smaller intensity of cosmic radiation there. From the calculated conductivity at all altitudes the resistance of a vertical column of atmosphere of unit cross-section was calculated. This is an important datum for various considerations in atmospheric electricity. It was found to be about 20 per cent greater near the equator than at about 50° latitude. The calculation of conductivity at the surface is consistent with observations of conductivity made on the *Carnegie* over the oceans in that those observations showed no dependence on latitude. The contrast in columnar resistance at high and low latitudes is quantitatively consistent with the smaller values of gradient observed at low latitudes during cruises of the *Carnegie* and provides an acceptable explanation of the latter observation.

The interpretation by Gish and Sherman of registrations of air-conductivity made on the flight of *Explorer II* also indicated that, although Aitken nuclei occur in negligible quantity in the altitude range 6 km to 18 km, yet from 19 km to 22 km they are present in sufficient abundance to reduce the air-conductivity to less than half the value which is to be expected in pure air at the highest altitude of the observations (22 km). This bank of nuclei apparently coincides in position with a corresponding bank of ozone. That this correspondence may be significant is indicated by the observations of Wait and Torreson that Aitken nuclei are formed in great abundance by the ultraviolet light from a quartz-mercury vapor lamp.

Although it is now established that a decrease in the intensity of cosmic radiation sets in at some altitude (16 km near the equator and about 24 km at 51° north magnetic latitude), yet, as proved by Gish and Sherman, the conductivity cannot decrease with altitude at any altitude unless some factor other than the observed decrease in cosmic-ray intensity is involved. From this and other considerations it now seems likely that there are factors, such as Aitken nuclei, which generally reduce the conductivity, in parts of the stratosphere, to values lower than those usually estimated. However, preliminary investigations of the effect of local pollution on the air-earth current led Gish to conclude that neither this nor other factors acting in the unexplored levels of the atmosphere can contribute as much as 50 per cent to the total resistance.

Some support for the foregoing conclusion is also provided by investigations by Sherman of the electrical conduction-current at College, Alaska, during the International Polar Year. The average magnitude and the diurnal variation of the current there is very near to that observed over the

oceans, especially for the winter months at College. From this it is to be inferred that the columnar resistance at College, especially in winter, is about the same as the average over the oceans and, if it varies during the day, the diurnal variation is the same.

Various observers have reported evidence that radio waves are returned from the troposphere and lower stratosphere. This has been interpreted by some investigators as pointing "to continuous ionization in sharply bounded thin strata, over long periods of 5×10^{12} ions/cc or more in regions around six to ten km . . . at all times of day, in summer and in winter." However, Gish and Booker pointed out that direct observations of the electrical state of the troposphere and lower stratosphere show that the electrical conductivity of these regions is something like nine orders of magnitude less than that suggested by those investigators. For example, continuous records of electrical conductivity obtained on the flight of the *Explorer II* up to an altitude of nearly 22 km show a maximum ionic density of only 5300 ions/cc (at 14.8 km). Other observations from balloons show no trace of ionic densities far in excess of 400 ions/cc throughout the troposphere. This evidence is further supported by the continuous records of air-conductivity obtained for 13 years at the Huancayo Magnetic Observatory, 3.3 km above sea-level. Moreover, they show by calculations that the power required to maintain the ionic concentration postulated in that interpretation is startling when compared with that available from the Sun and thunderstorms. They further conclude that the strength of radio echoes from the troposphere would seem to have been greatly overestimated.

The electrode-effect in the atmosphere. For the normal electric field the charge on the Earth's surface is negative, so that positive ions in the atmosphere drift toward the Earth while negative ions are repelled. Since negative ions apparently do not issue from the Earth to replace those which are repelled, the concentration of negative ions in the air near the surface is, with rare exceptions, less than that for positive ions. This is designated the electrode-effect. The most general mathematical theory of this thus far developed rests on some simplifying assumptions, the importance of which it is desirable to test by observed data. This was done by Sherman using measurements of positive and negative conductivity and of potential-gradient made at College, Alaska, during the Second International Polar Year. There is very little wind at that place in winter, so that the rate at which the air is mixed by turbulence is correspondingly small. In that season he found fact and theory to be in close agreement. In summer, however, the air-motion was sufficient to give rise to appreciable disagreement. The disparity between fact and theory can be expressed as a simple empirical function of wind-velocity. This then indicates approximately the extent to which mixing reduces the electrode-effect at the Earth's surface.

Electric convection near the Earth's surface in fair weather. The tendency of mixing to reduce the electrode-effect is equivalent, under normal circumstances, to the movement of negative charge toward the Earth. The electric convection effected in this way constitutes a component of the electric current between the atmosphere and the Earth. This convection-current is directed oppositely to the electric conduction-current and, since this is

doubtless a worldwide feature, it is important to ascertain whether, as some have claimed, it must be taken into account when considering the electrical equilibrium of the Earth. However, the magnitude estimated by Gish, in a study of the space-charge observations reported by Joseph G. Brown of Stanford University, is not more than 1 per cent of the average electric conduction-current in fair weather at an altitude of 1 m from the surface at that place. It is to be expected that in open country and at sea, where the most representative measurements of the conduction-current are made, the convection-current is even less than this estimate and can accordingly be neglected when considering observations at such places.

Worldwide variations in atmospheric electricity. From observations made at sea on cruises of the *Carnegie* it was first shown by S. J. Mauchly in 1921 that the diurnal variation in potential-gradient and that in the air-earth conduction-current are aspects of a worldwide phenomenon in that the variations are everywhere in unison. This has since been found to apply over land as well as at sea with certain exceptions which can be explained by local causes. These and other worldwide variations of atmospheric-electric phenomena are of interest because they are indirect manifestations of some characteristics of that elusive fundamental element in atmospheric electricity which may be called the supply-current. The worldwide diurnal variation in the conduction-current clearly indicates that the supply-current for the whole Earth undergoes a diurnal variation. Does it also vary from day to day or from year to year? The answer to that question may help to ascertain the origin of the supply-current and hence also the origin of the electric field and conduction-current in the atmosphere during fair weather. It was reported last year that Wait and Mauchly found some evidence of a tendency of the potential-gradient to vary in a similar manner from year to year at three widely distributed places (Ebro Observatory in Spain, Huancayo Magnetic Observatory in Peru, and Watheroo Magnetic Observatory in Western Australia). This investigation was extended by Mauchly in the summer of 1937 by taking into account the simultaneous variation of the air-earth conduction-current. Although the results did not definitely contradict those of the previous investigation, yet they indicated that because of numerous irregular variations more data must be examined before definite conclusions are drawn. In the course of this investigation Mauchly noted an apparent correlation between dates of radio "fade-outs" and dates of high diurnal range in temperature. However, the effect, if real, is small compared with the usual variations in the diurnal temperature-range from other causes such as cloudiness and rain, and therefore considerably more data must be examined by suitable statistical methods in order to test this possibility.

GEOELECTRICITY

Lunar diurnal variation in earth-currents. The investigation of the lunar diurnal variation in earth-currents, begun by Rooney during the last report-year, was continued using the records from Tucson and Huancayo for the year 1932. The monthly mean lunar diurnal variation was found to be quite definitely semidiurnal in character and its amplitude was found to be less

than one magnitude smaller than that of the solar diurnal variation. Harmonic analyses show that the amplitude of the predominant second harmonic is about one-sixth that of the solar diurnal variation at Huancayo and about one-fifth that of the solar diurnal variation at Tucson. The form of the mean curves is the same for both the equatorial station, Huancayo, and the middle-latitude station, Tucson. In this respect they differ markedly from the curves of solar diurnal variation.

The manner in which the lunar diurnal variation changes with the phase of the Moon was also examined. Both components at Huancayo show a marked increase in activity during daylight hours and a corresponding diminution during the night, so that the curves constructed for a given phase of the Moon are no longer of a simple semidiurnal character. These changes are similar to those found in the corresponding curves for the magnetic element. The Tucson data indicate that there is less difference between conditions during day and night affecting lunar diurnal variation at this middle-latitude station. Curves constructed for the individual phases of the Moon at Tucson remained predominantly semidiurnal with only a slight decrease in amplitude from day to night and comparatively small shifts in phase. It would appear that variations in the ionization of the *L*-layer are most effective in producing earth-current variations near the equator. The Tucson results are in good agreement with those obtained by Egedal and Rougerie, using the data from Ebro and Parc St. Maur, Paris, respectively, both of which are also middle-latitude stations.

Geoelectrical measurements in volcanological investigations. The advisability of including electrical measurements in the proposed comprehensive program for volcanological investigations in Guatemala was considered by Gish and Rooney. They concluded that two aspects of such measurements should be tried, namely, (a) a survey of earth-resistivity and (b) registration of natural electrical potentials in the Earth in the vicinity of the volcano. The resistivity-survey will doubtless yield an estimate of the depth of volcanic ash or other overburden and may help to extend knowledge of other hidden structure. The earth-potential measurements may serve as an indicator of the activity of deep-seated volcanic processes. Relatively large potential-differences between points on the Earth's surface are observed in mountainous regions. There are reasons for thinking that these arise from relatively deep-seated physical or chemical, or physico-chemical, processes which may have geological significance (see annual report for 1936-37). Furthermore, Palmieri observed an apparent relation between changes in such earth-potentials and the volcanic activity of Vesuvius. These are the chief reasons for expecting to find variations in the earth-potentials which correspond to changes in processes which are involved in volcanism. Prediction of volcanic activity is a practical goal of volcanological investigation. If the earth-potentials are associated with deep-seated processes of volcanism, they may assist in such prediction. The registrations which would serve this purpose could be made at a distance from the volcano, that distance being limited only by the expense of installing and maintaining a double-conductor cable or line similar to such as are used for telegraph- or telephone-service.

INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO TERRESTRIAL MAGNETISM

The origin of changes in the Earth's magnetism in the outer atmosphere was conceived some 50 years ago in the theories of Stewart and Schuster. They proposed that electrification of upper atmospheric regions would permit conduction of electrical currents which produced these changes. Direct experimental examination of the electrical state of the outer atmosphere was delayed until the development by the Department of radio "sounding" methods which permitted determination of the distribution of ionization through the outer atmosphere. This type of investigation shows that a complex structure of ionized regions or "layers" exists in this "ionosphere" of the Earth. Because the ionization of this atmospheric region is produced by sources external to the Earth, principally the ultraviolet light from the Sun, the ionosphere forms a region of transition in which effects originating on the Sun are translated into the geophysical effects observed on the Earth. Exploration of the ionosphere is therefore fundamental to an understanding of these geophysical, and in particular terrestrial-magnetic, effects which are produced through this chain of events.

The productive field of investigation which was opened during the past two years with the discovery that magnetic effects of the diurnal-variation type are associated with certain bright chromospheric eruptions, and accompanying radio fade-outs in the sunlit hemisphere, was pursued vigorously during the past year. Understanding of the underlying nature of the regular daily changes of the Earth's magnetism which has come through this approach has proved most illuminating. The results represent a most important advance in the science of terrestrial magnetism in recent years. It is an interesting commentary that the broader inferences of these physical effects are becoming apparent through collaboration of workers in diverse fields of physics who observe them in their different aspects.

The ionospheric investigations reported last year demonstrated that the radio fade-out—the sudden failure of high-frequency radio-wave transmission in the sunlit hemisphere, which coincides with certain bright chromospheric eruptions—must be due to the absorption of the radio waves in the lower ionosphere. It appeared that this was due to intense production of ions in the region between about 60 and 100 km above the Earth. The coincident magnetic effect was then explained as occurring because of an increase in electric current-flow in this region of increased electrical conductivity. Because the magnetic change was an augmentation of the diurnal variation of the Earth's magnetism, it was possible to deduce, from a detailed investigation of certain seeming anomalies, that this was also the region in which flowed the electrical currents which produce the magnetic diurnal variation.

Continuation of the ionospheric investigations by more exact and exhaustive methods has confirmed these views, and has narrowed the range of heights in which these current-sheets must be principally confined. Using the automatic multifrequency technique, it has been demonstrated that the radio fade-out effect occurs because of intense ionization produced below the

level of the E -region of the ionosphere by the ultraviolet light emitted from hot gases of the bright chromospheric eruption. Thus the more intense effects occur below a height of about 90 km. The upper regions of the ionosphere are unaffected by the passage of this ultraviolet light through them, experimentally demonstrating that the ionized regions must be produced by processes of selective absorption. The quantitative evidence thus obtained has stimulated further investigation of the physical properties of the outer atmosphere and of the processes of absorption and ionization involved in the production of the various ionized regions.

Beginning of continuous operation of the automatic multifrequency equipment for investigation of the ionosphere at the Huancayo and Watheroo magnetic observatories of this Department has been an important step in the advance of ionosphere-research. This equipment gives a continual record of the distribution of ionization through the whole of the ionosphere so far as it is possible to obtain it by radio sounding methods. The records permit investigation of the relation of ionospheric effects to solar and geophysical phenomena of which the investigation of radio fade-outs cited above is but one example. These records are disclosing new physical effects in the outer atmosphere hitherto unsuspected from earlier data obtained by cruder methods.

Investigations were instituted to determine the relation of the several regions of the ionosphere to magnetic disturbances or "storms." That the ionosphere must be related to magnetic effects of this sort is indicated both by theory and by the marked changes in long-distance radio-wave propagation coinciding with magnetic disturbances. The relation is not a simple one, for the nature of ionospheric fluctuations which occur at the time of magnetic disturbances changes with time of day and with season. While some of these features are apparent, it appears that a statistical treatment of the data will prove most fruitful in comprehensive examination of the relation. Heretofore lack of continual observation has hampered investigation of such effects but the introduction of the automatic multifrequency methods makes available a wealth of material for quantitative treatment.

A curious anomaly is found in the investigation of the maximum ion-density of the highest (F_2 -) region. Simple theory of ionization by ultraviolet light from the Sun predicts that ion-density should change with altitude of the Sun, and should be therefore a simple function of declination, latitude, and hour-angle of the observing station. This simple type of variation is observed for the normal maximum ion-densities of the lower (E - and F_1 -) regions. To explain the more complex changes of maximum ion-density of the upper (F_2 -) region, the concept of heating with consequent expansion of the outer atmosphere at small zenith-angles was introduced. This extended theory offered an explanation for the increased virtual heights of the F_2 -region which are observed in summer, but failed quantitatively to predict the variation of maximum ion-density for a station in one hemisphere from that in the other. A detailed analysis of the data obtained at Watheroo in the Southern Hemisphere and at Washington in the Northern Hemisphere shows that a further factor must be added empirically to the theory which accounts for a variation-component of maximum ion-density which occurs

at both stations in the same phase. This component has a period of one year, but it is not a seasonal component in the sense that such a component should differ in phase by six months in the Northern and in the Southern hemispheres. On the contrary, this non-seasonal or annual component reaches a maximum about January and a minimum about July at both stations. The origin of this variation-term is not yet known.

Extended analysis of the data also brings out the marked change of ion-density of the ionosphere with change of solar activity. Annual average maximum ion-density of the F_2 -region at noon has been linearly related to annual average sunspot-number during the rise of the present cycle of solar activity. Other regions are undergoing similar changes. Because the ionizing radiation is absorbed in the outer atmosphere, and cannot be seen from the Earth's surface, these investigations are extending our knowledge of solar radiation into the far ultraviolet spectrum—the more exactly as our knowledge of selective absorption-processes in the outer atmosphere increases. These far ultraviolet radiations are much more variable than the visible radiation, which is sensibly constant, and, being intimately associated with other little-understood solar variations, give a new approach to solar physical problems.

A most interesting development during the past year was the evaluation of the Lorentz polarization-correction in the ionosphere. The relation between the constitution of a conducting medium and its refractive index is a fundamental problem of classical physics to which attention has been devoted for many years but which even now is not completely solved. The question at issue is whether the force per unit-charge exerted by an electric field upon an elementary charged particle in the medium should be taken simply as the Maxwellian electric intensity \vec{E} (the Sellmeyer theory), or whether there

should be added a contribution $(4\pi/3)\vec{P}$ (the Lorentz theory), \vec{P} being the electric moment per unit-volume produced by the electric field in the neighborhood of the charged particle under consideration. For conduction of electrons in metals under the influence of steady and alternating electric fields ordinarily encountered, the Sellmeyer theory is universally taken for granted. There was some question, however, as to whether the Sellmeyer or Lorentz theory was applicable in the ionosphere, and this led to an extended theoretical discussion of the point. An experiment for deciding between the two theories depends upon reflection from the ionosphere of radio waves of frequency less than the gyromagnetic frequency. There is in middle latitudes a clear-cut distinction in the behavior of the extraordinary wave according to the two theories. Over the past year a large number of records showing magneto-ionic splitting of ionospheric echoes at these wave-frequencies was obtained at the Kensington Experimental Station of the Department using the automatic multifrequency equipment which for the first time has permitted such detailed observations. It appears impossible to interpret these observations in terms of the Sellmeyer theory but no objection exists to their interpretation in terms of the Lorentz theory. It appears therefore that it is the Lorentz theory which must be used in the ionosphere at wave-frequencies employed in ordinary broadcasting.

The program of ionospheric investigation was carried on by Berkner at Washington, by Stanton and Wells at Huancayo, and by Seaton and Hogan at the Watheroo Magnetic Observatory until April 1938, when the latter were joined by Berkner. With the installation of the automatic multi-frequency apparatus, the ionospheric program at the observatories was made a part of the regular schedule, with all observers taking part in maintenance of the program and in the reduction of the records obtained. The Department was fortunate to have also the services of Dr. H. G. Booker of Christ's College, Cambridge, England, as guest from September 15, 1937, during his sabbatical year's leave from Cambridge University.

RESULTS

Recording of data. The introduction of the automatic multifrequency recording equipments at the Huancayo and the Watheroo magnetic observatories represents the culmination of several years of research, development, and construction of a type of equipment capable of delineating the ion-distribution of the ionosphere as completely and continuously as possible at stations in the field. With this equipment successive observations of virtual height are made automatically at exceedingly small increments of wave-frequency change over the range of 0.516 to 16.0 mc/sec by determining the echo-time at each frequency. Each sweep through this frequency-range occupies 15 minutes, four sweeps being made each hour. In manner the virtual height of each ion-density through the range of ion-densities encountered in the ionosphere is measured, the ion-density required for reflection of the wave being proportional to the square of the wave-frequency of each transmitted pulse. From the curves thus formed on the photographic trace, the critical frequency of penetration, minimum virtual height, and other characteristics of each region are determined. Each record has a baseline which consists of thousands of pulses of about 100 microseconds' duration transmitted on wave-frequencies beginning at 16.0 mc/sec and spaced at small increments of frequency down to 0.516 mc/sec. The reflections from each transmitted pulse are recorded along the vertical scale, which is appropriately calibrated in virtual height as determined from the time for the pulse of waves to travel to the reflecting stratum and return. Because successive reflections from a given region form a coherent trace on the record, the resultant curves appear continuous as contrasted with the incoherent spots of interference and noise which are scattered on the trace in a random manner and therefore appear only as a slight fogging on the record. Care has been taken to adjust the character of the emission so that no interference to other radio services, through whose transmission-channels the emission must pass, would occur. The equipment has met with the full approval of the American, Peruvian, and Australian authorities in this respect.

Ninety-six of these records are obtained each day, and from them can be formed in three dimensions the picture of ion-distribution of the ionosphere in terms of ion-density with respect to height and time. Continuous recording of this nature was begun at the Huancayo Magnetic Observatory in November 1937, and at the Watheroo Magnetic Observatory in May 1938. Prior to these dates, more restricted measurements using the manual multi-

frequency technique together with fixed-frequency recording were made on regular schedule as described in previous reports. During the development of the equipment in the past year, an extended series of records was also obtained at the Kensington Experimental Station of the Department.

Analysis of the radio fade-out effect. Multifrequency observation confirms and extends the conclusions already drawn as to the nature of the radio fade-out effect from the fixed-frequency data reported last year. The duration of the fade-out as observed at normal incidence is an inverse function of the frequency of measurement. The commencement is not quite immediate on all frequencies, so that the time of commencement may appear slightly different to different observers, depending upon the transmitter-frequency, power, and location with respect to the subsolar point. The investigations indicate that no significant change occurs either in the virtual height or the maximum ion-density of the F_1 - or F_2 -regions during the fade-out. When the time required for establishment of equilibrium-conditions is considered for the several regions it appears most probable that no change in the F_1 - or F_2 -regions has occurred. A small increase in the ion-density and virtual height of the E -region which appears significant is observed. This is sufficient to account for the destruction of the normal E -region reflection-boundary previously described. Abnormal absorption of the wave continues after E -region conditions return to normal, confirming the view that absorption must occur below the level of maximum E -region ionization. It seems probable, therefore, that the intense ionization causing the fade-out occurs predominantly below the 100-km level, and probably below 90 km, the effect extending up into the E -region only slightly. The absorption of the ionizing radiation from the Sun which produces the fade-out must be negligibly small in the F_1 - and F_2 -regions to account for the stability of these regions during the fade-out. The radio fade-out can now be defined by the sudden extension upward in wave-frequency of the low-frequency absorption-limit which is determined by the lowest frequency on which reflections can be observed. This is ordinarily in the frequency-range of the radio-broadcast band. During intense fade-outs this low-frequency absorption-limit is projected through the entire frequency-range in which reflections can ordinarily be observed, thus blotting out all propagation from the upper regions of the ionosphere.

Ionospheric disturbances. Records obtained by the automatic multifrequency technique during magnetic disturbances indicate that in middle latitudes at night the maximum ion-density of the F -region is consistently decreased during disturbed periods. Accompanying this decrease is a great increase in the scattering of the wave, the reflections no longer coming from a well-defined height. Furthermore, the minimum virtual height is increased greatly and the reflection-intensity is noticeably diminished, multiple reflections often entirely disappearing during the more pronounced disturbances. This indicates a change from the normal well-defined layer-structure of the F -region to a diffuse region with a considerable inhomogeneity in density.

During daylight hours a slight decrease in ion-density of E - and F_1 -regions is observed as reported previously. Effects in the F_2 -region vary with season. In summer in middle latitudes the ion-density of this region decreases

violently during more marked disturbances, often falling to a value less than the maximum ion-density of the F_1 -region so that the F_2 -region may be invisible behind it for some hours at a time. The effect is accompanied by a marked increase in virtual height. During a winter day, however, the ion-density tends to increase slightly at the onset of the disturbance, later decreasing markedly for the more pronounced disturbances.

Commencement of automatic multifrequency recording at Huancayo has been so recent that detailed analysis of these records for magnetic effects has not yet been possible. Perusal of these records, however, indicates that conditions observed in middle latitudes are modified in equatorial regions in several important respects. The study is not sufficiently advanced, therefore, to permit generalizations, but rather to indicate the most profitable direction of the investigation.

In addition to the effects associated with magnetic disturbances, there occur at times violent increases or decreases in ion-density of the F_2 -region lasting over a period of a day or more, which do not appear to be connected with a particular magnetic disturbance. These might be considered as "ionospheric storms" of a special type.

Analysis of fluctuations of F_2 -region ion-densities. Observation of F_2 -region ion-density in the Northern and Southern hemispheres indicates that variations of maximum ion-density are inconsistent with the hypotheses which have been advanced to explain them. In order to determine the quantitative nature of the discrepancy, the data from the Watheroo Magnetic Observatory and from the National Bureau of Standards at Washington have been analyzed. It has been reported previously that observed variations at Watheroo and at Washington were not simply reversed in phase as expected from calculation of supposed seasonal effects. On the contrary, it appeared that a variation-component of large amplitude and of period of approximately one year occurred in the same phase at both stations. In the recent analysis, a simple method is used to separate the variations having opposing phase in the two hemispheres from the background appearing at both stations. Over the three-year interval analyzed from 1935 to 1937, a large variation-component exists which is in the same phase at both stations. This has a principal period of one year and an amplitude approximately equal to the amplitude of the component of variation which is in opposite phase at the two stations. It is not a seasonal variation in the sense that such a seasonal variation must be the same function of local zenith-angle in the two hemispheres and, therefore, should have a phase which differs in the two hemispheres by six months. The maximum amplitude of this term appears in January and the minimum in July at both stations simultaneously. The fact that the in-phase variation-component has a period of one year strongly suggests that it is related to the Earth or its motion. Less critical examination of the data from five other stations in both hemispheres indicates a dip in maximum noon ion-density of the F_2 -region in July at each station, suggesting that the effect is a general one. It therefore appears necessary to add empirically a correction-term to existing theories which accounts for this in-phase fluctuation if they are to predict the ion-density in any location.

It is found that the rise in annual averages of noon ion-density has an almost perfect correlation with annual average sunspot-numbers over the three-year period during the present rise in solar activity. This can be expressed quite closely by the expression

$$\bar{N} = (3.7 + 1.1\bar{R})10^8 \sqrt{\cos z}$$

where the Lorentz polarization-correction is assumed as zero. There appears to be no correlation, however, between deviations of the in-phase fluctuations of ion-density from the curve through annual means and corresponding short-time fluctuations of sunspot-number. Therefore the in-phase variation-component cannot be readily explained by resort to sunspot-changes.

The Lorentz polarization-correction. Experimental determination of the Lorentz polarization-correction is an excellent example of the use of the ionosphere as a low-pressure region unbounded by sidewalls for the conduct of physical experiments. The experiment was made possible by the advanced experimental technique of the Department described above. The experiment depends on the fact that, for radio waves, the ionosphere is rendered doubly refracting by the influence of the Earth's magnetic field. Free electrons in the ionosphere gyrate around the Earth's magnetic field with a frequency in the order of a megacycle per second. For wave-frequencies less than the gyromagnetic frequency there is, under suitable conditions, a clear-cut distinction in the behavior of the extraordinary wave according to the Sellmeyer and to the Lorentz theory. The distinction becomes apparent when measuring the variation of echo-retardation with frequency below the gyromagnetic frequency in certain regions of the Earth. Where the magnetic dip is greater than 35° but less than the value at which vertical propagation in the ionosphere at wave-frequencies under consideration passes from quasi-transverse to quasi-longitudinal type, the distinction between the two theories is the following. According to the Sellmeyer theory, the virtual height of the extraordinary wave increases to infinity as the wave-frequency increases to the gyromagnetic frequency. However, on account of strong absorption of this wave-component in the immediate neighborhood of the gyromagnetic frequency, it would be impossible to trace the extraordinary wave to an enormous virtual height at a wave-frequency just below the gyromagnetic frequency. On the other hand, according to the Lorentz theory, the virtual height of the extraordinary wave increases to infinity as the wave-frequency increases to a value known as the Lorentz frequency and which is definitely below the gyromagnetic frequency. Moreover, the absorption of the extraordinary wave just below the Lorentz frequency according to the Lorentz theory is less than it is just below the gyromagnetic frequency according to the Sellmeyer theory.

At the Kensington Experimental Station, where the magnetic dip is between 71° and 72° , the Lorentz frequency, neglecting the effect of heavy ions, is about 17 per cent less than the gyromagnetic frequency. Moreover, the reflection-coefficient of the extraordinary wave just below the gyromagnetic frequency according to the Sellmeyer theory is about four orders of magnitude less than it is just below the Lorentz frequency according to the Lorentz theory. The ionospheric records obtained at this station show

echoes which tend to infinity as the wave-frequency increases to 1.38 mc/sec. At a frequency slightly below 1.38 mc/sec it is actually possible to recognize the individuality of successive echoes, the wave-frequencies of which differ by known amounts, and to deduce that the virtual height is here increasing with increase of wave-frequency at about 100 km per kilocycle per second. These echoes can be traced to enormous retardations corresponding to virtual heights exceeding 1600 km per second. It appears from this immediately that return of echoes from such great heights as the retardation tends to infinity is incompatible with the large absorption expected on the basis of the Sellmeyer theory. Furthermore, the value of the gyromagnetic frequency at Kensington is 1.61 mc/sec, and if it decreases with increase in height according to the inverse cube of the distance from the Earth, it has a value of 1.54 mc/sec at a height of 100 km and 1.44 mc/sec at 250 km. The records show that prominent among the multiple echoes of this reflection are echoes which, in addition to having traveled up to the *F*-region and back again, have been reflected back and forth between the *E*- and *F*-regions one or more times, suffering partial reflection from the top of the *E*-region. The consequent additional retardation suffered by these multiple echoes is almost independent of wave-frequency. This confirms the theoretical expectation that the large retardation experienced by the echoes just below 1.38 mc/sec takes place in the lower part of the *E*-region, where it can be shown by both theory and experiment that the gyromagnetic frequency must be greater than 1.5 mc/sec. The interpretation of these observations in terms of the Sellmeyer theory therefore seems impossible. The observations can, however, be explained in terms of the Lorentz theory. To obtain a good quantitative interpretation, it is necessary to realize that good theoretical reasons exist for believing that considerable numbers of molecular ions exist in the lower part of the *E*-region, and that these somewhat affect the value of the Lorentz frequency. This concept is a powerful tool in determination of molecular-ion concentrations in the lower ionosphere. The ratio of molecular ion-density to electron-density in the lower part of the *E*-region turns out to be about 10,000. Heavy ion-concentrations of this magnitude are required to explain satisfactorily the diurnal variation in terrestrial magnetism.

COOPERATIVE ENDEAVOR

The Department cooperated with Dr. C. T. Kwei of the Central China College, Wuchang, in investigatory work on the ionosphere. In the fall of 1937, a manually operated ionospheric equipment, as designed at the Department according to a scheme proposed by T. R. Gilliland of the National Bureau of Standards, was installed in the Physics Department of the Central China College, at Wuchang (latitude 30° 34' north, longitude 114° 21' east). With this apparatus a single operator can make necessary readings of the virtual heights and critical frequencies. From data for noon-hour runs from October 1937 to January 1938 and from April to June 1938, and half-hour evening runs in March and April 1938, it is found that the critical frequencies at Wuchang are higher than those at Washington for both the *E*- and *F*₂-layers during the same months. The *E*-layer critical frequency, as observed also in other places, reaches a maximum

near local noon, whereas, for the F_2 -layer, the critical frequency attains a high value about 14° , maintaining nearly the same level until about 17° , 120° east meridian time. When plotted month by month, the E -region critical frequency increases with the approach of summer while the F_2 -layer critical frequency has a tendency toward a minimum in July with two probable maxima in October and April. This seems to indicate that the seasonal characteristics at Wuchang approximate those of Watheroo rather than those of Washington, but the data available are not sufficient to verify this point. Very frequently the virtual height of the E -layer undergoes a dip on the appearance of a higher layer and continues to keep its normal height long after the upper layer has appeared. In a few cases, the E -layer echoes persist even after the penetration of the F - and F_2 -layers. Magnetic splitting is quite evident especially in the day readings. The observed mean value of 620 kc as the difference between the ordinary and extraordinary components of the F_2 -layer penetrating frequency agrees well with the theoretical value of 614 kc.

Close contact must be maintained by the Department with other investigators in this field because of the worldwide aspects of the problem. In order that the data may be most widely disseminated, arrangements have been made for quarterly publication of the ionospheric information obtained at the observatories in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, and the data are prepared with this end in view. The Department also maintains cooperation with other workers, that the more important information obtained elsewhere may be available also for study.

The fourth annual Conference on Ionospheric Investigations was held at the Department on April 30, 1938. It was attended by forty investigators from the Bell Laboratories, the Radio Corporation of America, the National Bureau of Standards, the Department, and numerous universities and other organizations. Subjects discussed were: transmission-conditions and magnetic activity; variations in transmission-conditions; radio transmission in the troposphere and stratosphere; Lorentz correction for polarization; developments in methods of investigation; and absorption of solar radiation in the ionosphere. Considerable interest centered about the relation between radio transmission and magnetic activity. Recognition was given the service of the Department in compiling regular bulletins of the American magnetic character-figure and supplying them to interested investigators.

While en route to the Watheroo Magnetic Observatory, Berkner visited the Cavendish Laboratory at Cambridge and the Imperial College of Science and Technology at London to confer with Professors Chapman and Appleton, and others actively engaged in various phases of ionospheric research.

Among distinguished visitors at the Department during the year to study methods of and equipment for ionospheric research were Dr. A. R. Hogg of the Commonwealth Solar Observatory of Australia, W. C. Gee of the Federated Malay States Posts and Telegraph Department, Dr. Yoji Ito of the Naval Reserve Laboratory of Japan, and Professor G. W. Kenrick of the University of Puerto Rico. Upon request complete sets of blueprints showing design and construction of the multifrequency ionospheric recording equipment were supplied Professor E. V. Appleton of Cavendish Laboratory, Cam-

bridge, England, Dr. Yoji Ito of the Naval Research Laboratory, Tokyo, Japan, and Professor M. N. Saha of the University of Allahabad, India.

INSTRUMENTAL DEVELOPMENT

A further investigation of antenna-design for most suitable use in connection with the automatic multifrequency equipment was conducted theoretically and checked experimentally at the Kensington Experimental Station. This dealt principally with adjustment of length and height to values such as would least affect the radiation-pattern in the upward direction with changing Earth conditions and would maintain the most uniform upward radiation over the whole range of wave-frequencies. The antenna-structure finally designed maintains upward radiation sensibly uniform at all frequencies for constant power-input, and is little affected by changing ground-conditions.

The development of a suitable constant-frequency controller capable of holding the speed of a one-kilowatt alternating-current generator to a high degree of precision was completed at the Watheroo Magnetic Observatory. Inasmuch as the standards of virtual height and wave-frequency along the ionospheric records depend upon the speed of rotation of the associated synchronous driving mechanisms, especially good frequency-control of the generating equipment is necessary. The present controller is capable of maintaining constant speed to about one part in 50,000 when operated from a temperature-controlled tuning-fork. The speed of the generator is maintained constant by means of a gas-discharge tube controlled from the tuning-fork, with associated circuits to prevent phase-changes with the wide range of input-voltages experienced in the field.

Kensington Experimental Station. Operation was continued at the Kensington Experimental Station of the Department near Kensington, Maryland, involving principally development and test. This station operates under the special and general experiment radio licenses W3XI and W3XFE. Continued occupancy of this station was possible through the courtesy of Colonel M. K. Barroll, U. S. A. (retired), who maintains an active interest in this work.

MAGNETISM AND ATOMIC PHYSICS

FORCES AND INTERACTIONS GOVERNING THE PRIMARY PARTICLES OF MATTER

Magnetic movement and angular spin have been found, perhaps somewhat unexpectedly, to be among the very few properties or attributes intrinsically possessed by the smallest particles of matter, as distinguished from those properties which arise when numerous particles interact with each other. Experiments in the laboratory designed for the study of the interactions of the primary particles of matter under the least complex conditions, for example, the collision of a single proton with another single proton or single neutron (a proton is the positively charged nucleus of a hydrogen atom, and a neutron is a similar particle having zero electrical charge), accordingly have been the principal feature of the Department's program on fundamental physics in relation to magnetism during the past decade.

There are several other broad problems open to experimental attack for

which an excellent case can be made as relating perhaps more immediately to the specific field of terrestrial magnetism. The radio-echo method for study of the upper atmosphere, contributed in 1925 by the Department and now such a fruitful part of the observatory-program on terrestrial magnetism throughout the world, is a historical illustration of the point. The discovery of the radio echoes and the demonstration of the powerfully analytical virtues of this method for upper-air investigation stand as a fundamental contribution by the Department to the field of geophysics. Today one may predict, for example, that further study in the laboratory of the properties of matter under exceedingly high pressures, utilizing the cascade-principle to extend the limits of previous work, offers an opportunity for important contribution to basic physical knowledge, having also direct relation to the Earth's magnetic properties. Suggestions for novel apparatus and a new attack in this direction in fact developed in the Department's laboratory during 1936; this and the modulated-searchlight method for upper-air studies (see previous reports) are typical of the possible experiments which would emphasize the approach through the laboratory, as contrasted to that through the observatory, toward the general field of Earth physics.

One cannot ask for a more fruitful and far-reaching result, however, than the achieved first direct experimental determination of the enormous attractive forces at short distances which are exhibited by the heavy building-blocks of matter—protons and neutrons—which has resulted from concentrating efforts on the "simplest" kinds of problems which can be formulated regarding the primary particles of matter. Since initiating the Department's program the subject has even acquired a distinct name of its own: nuclear physics. The attractive forces between the primary particles are called nuclear forces, being responsible for the aggregation of groups of protons and neutrons to form the nuclei of all atoms of the chemical elements.

Following years of technical development toward this announced objective, the first measurements on these proton-proton and proton-neutron forces are described in the reports for the past two years. During this report-year further detailed observations were made, giving measurements entirely independent of the earlier series and—a point of particular importance—calibrated in terms of absolute units (centimeters, grams, seconds). The reduction to an absolute scale, done indirectly in the previous work, vitally affects the exact significance of the measurements. It was done by measurements on the collisions of high-speed protons with helium, nitrogen, oxygen, and argon nuclei, using the same apparatus and technique as for the observations on proton-proton collisions which give a measure of the proton-proton forces. Details of these observations are given in the published technical papers.

THE ATOMIC-PHYSICS OBSERVATORY

The construction of a high-voltage equipment for nuclear physics, having adequate range and characteristics for a comprehensive program of precision measurements, was the chief feature of the work during this report-year. Despite the demands of this work on the staff, it was possible by careful planning and administrative support to keep both target-positions of the existing one-million-volt equipment in full operation daily on the

two main scientific problems described in the paragraphs above and below. As the report-year closes the summer humidity has stopped these observations (the new equipment has humidity-control) and all members of the staff are pushing the new equipment toward its first high-voltage tests.

The new equipment comprises a constant-potential (electrostatic) generator and vacuum-tube designed to reach potentials in excess of five million volts under precise control. Insulation is by dry air compressed to 50 pounds per square inch in a pear-shaped steel tank 55 feet high and 37.5 feet in diameter, and adequate provision is made for shielding observers and instruments (against penetrating radiations) and for auxiliary equipment. Similar equipments are being constructed at the Westinghouse Research Laboratory and the University of Minnesota under the direction of former members of the Department's staff and based directly on the designs and technique developed here; other units are being planned elsewhere.

A technical problem of considerable interest which was met and solved in the construction of the new equipment was that of the mechanical stability of the high-voltage unit. This consists chiefly of a 12,000-pound steel ball (19 feet in diameter) supported 26 feet above the grounded base (inside the steel tank) on four porcelain pillars, six feet on centers. The unreliable mechanical properties of porcelain under any type of stress except compression are well known. Bending moments in these tall supporting columns, arising from motions of the base (outer tank) due to winds, and motions of the high-voltage ball itself due to main belts and machinery, had to be taken care of without allowing tension or excessive shear in the porcelain. The requirement was met by providing a succession of stiff steel platforms intermediate between the base and the high-voltage ball. The porcelain supports are then in the form of short columns of small slenderness ratio between successive platforms. Rubber pads at each end of each porcelain, and at the four base-corners, permit the system to take up several hundred foot-pounds of energy without excessive stresses on the porcelains or elsewhere. Tests on the completed mechanical structure have verified its calculated stability and limits of safety. The cooperation of the National Bureau of Standards in the tests for wind-motions of the large steel tank and in loan of surplus porcelain insulators for construction of the support columns is gratefully acknowledged. Certain features of the new equipment are designed with reference to its use for producing X-rays at very high voltages; some of the measurements on these are planned in cooperation with the National Bureau of Standards investigators as an extension of its present X-ray measurements.

NUCLEAR STRUCTURE—A NEW ISOTOPE OF BERYLLIUM

The actual laws governing the behavior of the strong attractive forces between the primary particles of matter in forming atomic nuclei have not yet been established. This is the problem of nuclear structure, and it appears to be inherently a many-body problem, in contrast to the problem presented by the outer (electronic) structure of the atom. The latter has been successfully treated in terms essentially of the separate motion of each particle, as influenced by the average field due to the rest of the

particles. Because of the extremely small size of an atomic nucleus (10^{-12} cm), and the comparable range of the intense nuclear forces, each particle in a nucleus, however, appears to be at all times strongly influenced by every other particle. This means that a detailed description of nuclear dynamics is well-nigh humanly impossible, except for the simplest cases of nuclei composed only of two or three particles. In view of this situation a considerable part of the available time has been spent during the past several years on detailed and quantitative measurements of all nuclear processes involving the two lithium isotopes, which are comprised of six and seven primary particles, respectively, in order to obtain as extensive information as possible regarding the simplest examples, so to speak, of the complex nuclear structures of all heavier chemical elements.

The discovery in the Department's laboratory during this report-year of a hitherto unknown isotope of beryllium of mass seven is an illustration of the type of information sought in these studies. This isotope, Be^7 , has been demonstrated to occur as a product in several reactions of lithium and boron; it is a radioactive isotope with a half-life of about 43 days which reverts to Li^7 , the normally stable nucleus of mass seven. The radioactivity in this case is unusual, however. The experiments have shown that the normal (unexcited) configuration of Be^7 has such a low energy that radioactivity cannot occur in the usual way by the expulsion of an electron (positron) from the nucleus; there is not sufficient potential-energy available to create the rest-mass of the electron. The transition to Li^7 hence can only occur by the capture of an external (negative) electron, usually no doubt from the K-shell of the parent atom. "Silent radioactivity" of this kind is known for a few heavier chemical elements, but the case of Be^7 is of special quantitative interest for two reasons. K-electron capture should be a distinctly rare event with a nuclear charge as low as four (beryllium) and, second, the capture in this case can occur in either of two ways: by the emission of a high-energy neutrino (about 1 mev), leaving the resultant Li^7 in the normal state, or by the emission of a medium-energy neutrino (about 0.5 mev), leaving the Li^7 in its 440-kv excited state; it then subsequently reverts to the normal state by the emission of a gamma ray. Measurements of these gamma rays have thus given experimental information concerning the relative probability of emission of neutrinos of different energies. This question has hitherto not been experimentally accessible. The basic importance of the so-called neutrino problem—another name for the apparent lack of conservation of energy in those nuclear processes which involve loss or capture of electrons—makes the data of these experiments particularly welcome.

THEORETICAL-PHYSICS CONFERENCE

A fourth "Washington Conference on Theoretical Physics" was held March 21 to 23, 1938, under the joint auspices of the George Washington University and of the Institution, acting through this Department. The subject of nuclear physics has developed so rapidly during the past few years that laboratory-data are now available with regard to nearly all the nuclear reactions which might conceivably serve as sources of energy for the stars.

That the great lifetimes of the Sun and the stars, pouring out inconceivably vast amounts of radiant energy each second of their existence, must be ascribed in some way to actions of the nuclear forces seems evident. The subject of this year's Conference was "The problem of stellar energy," and eleven investigators in astronomy, astrophysics, and theoretical and experimental nuclear physics were brought together for three intensive days of technical and informal discussion. About twenty visitors also attended the various sessions. The purpose of this Conference was to examine the extent to which definite conclusions could already be drawn or limits set regarding the mechanism of the energy-supply inside a star, primarily with a view toward guiding the next immediate efforts of investigators in the various fields relating to this important problem. Resonance processes and highly condensed "star-nuclei" were among the important technical features under discussion. The Conference produced gratifyingly definite results in three directions. Several tentative theoretical proposals regarding the mechanism of stellar energy-supply were ruled out very definitely on the basis of the measurements in the laboratory during recent years on nuclear processes. In addition, it was shown numerically that none of the ordinary nuclear processes satisfies the stellar requirements, limiting the search to two or three rare but possible reactions not as yet established in the laboratory. A third result, subsequent to the meeting here, was the suggestion of a reaction-chain involving carbon by one of the members of the Conference, which appears to fulfill in large measure the requirements set. Quantitative investigation of the several definite questions, both theoretical and experimental, which were raised during this Conference is already resulting in accelerated progress on the problems of stellar energy.

MISCELLANEOUS

Experiments and other activities not directly a part of the current program, aimed at two or three fundamental objectives, have been kept at a minimum during the report-year, since about half of the available time has had to be spent on the new high-voltage equipment under construction. As soon as this new equipment is in operation, experimental data on these supplementary, but often very important, problems can be successfully obtained with much less expenditure of time and effort than is required with the present one-million-volt installation. Some preliminary observations using radioactive sulphur and one or two other radioactive "tracers" in chemical studies have been made. Applications of this technique to certain fundamental problems in biology are planned in cooperation with investigators outside the Department. Mutation-studies, using gamma rays and neutrons, in cooperation with the Institution's Department of Genetics, were interrupted, to be resumed on completion of the new equipment. Observations on the background light of the night sky verified the earlier indirect estimates and made it clear that no serious difficulties are to be expected in the use of the modulated-searchlight method for study of the upper air. A few observations on the searchlight beam at low altitudes showed the necessity for a steady and accurately oriented field-mounting for the receiving mirror. The beam is

invisible at great heights, and the setting of the receiver must be made entirely by instrument.

Several hundred technical and scientific visitors gave our work detailed personal inspection during the past year. As most of these men are engaged in or are beginning researches similar to our own, their visits and questions are welcome, but record should perhaps be made of this more or less incidental contribution by the Department's laboratory to scientific progress.

The staff during the year included Hafstad, Heydenburg, Meyer, Roberts (Carnegie Institution Fellow), Rumbaugh (guest-investigator to September 1, 1937), Schmidt (laboratory apprentice), and Tuve. Professors Breit (University of Wisconsin) and Gamow (George Washington University), as research associates, gave much valuable assistance, as also Professor Teller of George Washington University.

PUBLICATIONS

Publications relating to the above investigations are noted in the bibliography below.

Formal talks were presented as follows: Washington Physics Colloquium, November 24, 1937, by Hafstad on "Progress-report on the new high-voltage equipment" and December 8, 1937, by Hafstad on "The neutron reactions of lithium"; Study Club of Washington Dentists, December 6, 1937, by Hafstad on "The Atomic-Physics Observatory"; Pittsburgh Physics Colloquium, February 3, 1938, by Hafstad on "Proton-proton scattering"; General Electric Research Laboratory Colloquium, Schenectady, February 4, 1938, by Tuve on "The structural forces of atomic nuclei"; Chevy Chase Masonic Lodge, February 9, 1938, by Tuve on "The new Atomic-Physics Laboratory and its work"; Washington Physics Colloquium, February 16, 1938, by Teller on "The origin of galaxies in an expanding universe"; Carnegie Institution Lecture, Washington, March 1, 1938, by Tuve on "The forces which govern the atomic nucleus"; Washington Section, American Institute of Electrical Engineers, March 8, 1938, by Tuve on "Investigating the structural forces of the atomic nucleus with high voltages"; Philosophical Society of Washington, April 9, 1938, by Gamow on "The fourth Washington Conference on Theoretical Physics"; Washington Meeting, American Physical Society, April 28, 1938, by Heydenburg on "The scattering of protons and deuterons by deuterium and by helium"; Washington Meeting, American Physical Society, April 29, 1938, by Roberts on "The formation of Be'."

COOPERATION IN NUCLEAR PHYSICS AT UNIVERSITY OF WISCONSIN

Professor G. Breit, of the University of Wisconsin, continued as research associate and consultant. The following paragraphs summarize briefly work done by him and his associates at the University of Wisconsin.

Proton-proton scattering. Work has been continued on the theory of scattering of protons by protons. Previous calculations in connection with the measurements of Tuve, Heydenburg, and Hafstad have given a fairly complete picture of the theoretical possibilities in the region up to 1000 kv. Computations were made on the effects of various types of interaction in the higher-energy region up to 2800 kv and work is in progress for energies

up to 10,000 kv. The calculations show a greater sensitivity of observed scattering to range than in the lower-energy region. [Some of the results are shown in comparison with the measurements of Herb, Parkinson, and Kerst in figures 1, 2, *Review of Scientific Instruments*, vol. 9, p. 63, 1938.] Above 1400 kv these measurements show a marked deviation from the type of dependence of scattering on angle that is to be expected owing to the phase-shift K_0 that represents the spherically symmetric scattering anomaly. The direction of the deviations is such as would be expected for repulsive interactions of angular momentum 1 (p -anomaly) and attractive interactions of angular momentum 2 (d -anomaly) in units \hbar . Neither these data nor newer observations obtained and available from the Department of Terrestrial Magnetism offer convincing proof of the existence of the p - and d -waves. The dependence of the observed deviation on angle is such that one needs both the p - and d -waves, and their variation with energy is such that it does not appear to be reasonable theoretically. Newer measurements by Herb and collaborators are being made.

The coupling between anomalies with different values of the orbital angular momentum due to terms of the type $(\sigma_1 r)$ $(\sigma_2 r)$ had to be considered in this connection because it might be expected to cause a d -wave anomaly at lower energies than if the spin-radius coupling were absent. The absence of a 3S -condition of colliding protons which follows from the exclusion principle causes a disappearance of first-order effects of this type and speaks for the reliability of estimates of p - and d -wave anomalies by the more elementary methods previously used. The above work was done in collaboration with Thaxton and Eisenbud. Simplifications for carrying out computations of Coulomb wave-functions by means of a numerical evaluation of a definite integral have been made in collaboration with L. Hoisington. The above work was done in preparation for analysis of newer data when these should be available.

Fine structure of nuclear levels and relativity. The fine structure of atomic levels is understood at present as a relativistic effect. It is probable that nuclear levels have a fine structure of a similar origin. In order to understand the possible effects it was necessary to consider the possible relativistic effects for forces of non-electromagnetic origin. For relatively low velocities it was possible to develop such a theory. Some of this was mentioned in the annual report for 1936-37. Since then the mathematical structure of the theory was somewhat enlarged by considering the collision between particles. Possible types of interactions have been set up that give in the first order of Born's method results that are consistent with restricted relativity for any velocity of the colliding particles. Other related forms have been shown to give invariant descriptions of the collision-process for the exact solution of the wave-equation but with the restriction to first-order effects in v^2/c^2 where v is the velocity. These considerations suggest the presence of interactions of the spin-radius and the spin-spin type that have been mentioned in the section on proton-proton scattering.

Consequences of this theory for the relativistic effects of the deuteron have been studied in collaboration with S. Share. It was found that the possibilities left open by the theory allow considerable latitude in the value

of the correction. This shows up an intrinsic uncertainty in the value of the binding energy due to non-relativistic effects. The exact fitting of the binding energies of H^3 , He^4 by assumed forces neglecting relativistic effects appears therefore to be questionable.

The spin-orbit interactions that follow from the above theory have been computed, using approximate wave-functions, for the ground state of Li^7 in collaboration with J. R. Stehn. It was found possible to obtain a fit to the supposed value of the splitting of the ground-level (~ 450 kv). The fit was not obtained, however, by using the simplest form of the theory and the interpretation of the first excited level of Li^7 as a fine-structure component of the ground-level is somewhat open to doubt. This doubt is strengthened by the study made by Rumbaugh, Roberts, and Hafstad on the relative intensities of the proton groups from $Li^6 + H^2$ and the slight indication present in the data of Cockroft and Lewis of a more closely spaced fine-structure in C^{12} .

Saturation-conditions. If the forces of attraction between nuclear particles were due to ordinary potentials, the binding energy of nuclei would increase at least as fast as the square of the atomic number. There would then be in Nature very heavy stable nuclei. This is contrary to experience. For this reason exchange-forces are introduced into nuclear theory. There are at present three types of most commonly used exchange-forces and the potential energy between two nuclear particles is supposed to be a sum of an ordinary potential and these three types of exchange-forces. The possible overstability of heavy nuclei must be prevented by a judicious choice of the coefficients of the four types of potential. These conditions are called *saturation-conditions* because the overstability of heavy nuclei can be prevented by having saturation of the binding capacity of the nuclear particles.

Some conditions have been previously known to be necessary and some of them have been known to be sufficient for saturation. In collaboration with E. Wigner the necessary and sufficient conditions have been ascertained and systematized, making use of additional approximate information derivable from the nonexistence of stable nuclei heavier than N^{14} with odd atomic number and even atomic weight. The saturation-conditions can be represented in a two-dimensional diagram which then shows also the probable proportions of the four types of interaction.

Calculations were made in collaboration with E. Wigner on the disintegration of Li^8 into two alpha particles (Rumbaugh, Roberts, and Hafstad) and an electron. The approximate effect of resonance to the first excited state of Be^8 is estimated. These calculations are not quite finished.

Calculations are in progress in collaboration with J. Knipp on the capture of the K-electron by Be^7 discovered by Rumbaugh, Roberts, and Hafstad at the Department of Terrestrial Magnetism. They give evidence that the mass-difference ($Be^7 - Li^7$) cannot exceed the 2-mc^2 requisite for positron emission by more than 60 kv on the Fermi theory and 200 kv on the Konopinski-Uhlenbeck theory. They also indicate that the many-body aspect of the nucleus becomes noticeably more important from atomic weight 7 to 11.

Isotope-shift. Meissner's observations on the isotope-shift of Mg are interpreted as a mass-effect enhanced by a perturbation of the p^2 -configuration by the sd -configuration.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The collection, compilation, and discussion of data pertaining to the world magnetic survey were continued. Green, Chief of Section, was in charge at Watheroo Magnetic Observatory, while at the office Wallis gave full time and Forbush, Johnson, and Vestine gave part time to this work. Parkinson did field-work in the Pacific islands, Australia, Malaya, Siam, Indo-China, and Dutch East Indies. Wallis and Vestine have well under way preparation of manuscript on land-results from 1927.

Cooperation was continued with the Aerial, Geological, and Geophysical Survey of Northern Australia through the loan of magnetometer-inductor 18, and with the Adelaide Observatory of South Australia through the loan of magnetometer 6. Some magnetic data in the Arctic were obtained in cooperation with the MacGregor Arctic Expedition.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Brief accounts of field-operations referred to above are given in more detail below.

Africa. Secular-variation data were obtained through control-observations at the Cape Town Magnetic Observatory.

Upon request the detailed results of observations made in Portuguese East Africa and neighboring territories, with descriptions of stations, were supplied to the Director of the Lourenço Marques Observatory. Similar compilations of data in South Africa, Southern Rhodesia and Northern Rhodesia, and Portuguese East Africa were supplied upon request to the Director of the Magnetic Survey of South Africa.

Asia. The following stations were occupied by Parkinson: six stations in Malaya, namely, Singapore, Malacca, Kuala Lumpur, Ipoh, Penang, and Alor Star; five stations in Siam, namely, Tung Song, Chumphon, Hua Hin, Bangkok, and Aranya Pradesa; five stations in Indo-China, namely, Siemreap, Pnom Penh, Saigon, Hanoi, and Vinh. At Chumphon the high value of horizontal intensity of 0.40759 CGS was observed. On the return to Australia, a stop was made at the Batavia Magnetic Observatory in order to compare magnetometer-inductors 13 and 28 with the observatory-standards and to redetermine instrumental constants. No. 13 had previously been sent to China for use in the magnetic survey of that country in cooperation with the Research Institute of Physics, Academia Sinica, Shanghai. Subsequently, it was seen that disturbed conditions in China would prevent further field-work there for some time to come. No. 13 was therefore shipped to Batavia for use in the intercomparison and constant-determination program, after which this instrument was forwarded to Dr. A. Walter, Director, British East Africa Meteorological Service, for use in the magnetic survey of East Africa. After completing the work at Batavia, Parkinson sailed for Fremantle on July 6, 1938.

Australasia and Pacific islands. The extensive program of field-work in Australasia and the Pacific islands, inaugurated in 1936, was continued by Parkinson. In July 1937, observations were made at Honolulu Magnetic Observatory for the intercomparison

of magnetometer-inductors 13 and 28 and the standards of the Observatory. En route from Honolulu to Sydney, magnetic observations were made at Suva, Fiji Islands. Following a reoccupation of the magnetic station at Blacktown, near Sydney, another expedition into the Pacific resulted in the occupation of the following stations: three stations in New Hebrides, namely, Luganville, Port Patterson, and Port Vila; four stations in Tahiti, namely, Papeete, Tautira, Taravao, and Motu-Uta; two stations in New Caledonia, namely, Noumea and Bourail. After returning to Sydney, the magnetic station at Blacktown was reoccupied for a recomparison of magnetometer-inductors 18 and 28, the former instrument being used by Richardson of the Aerial, Geological, and Geophysical Survey of Northern Australia. On the way to Asia, Parkinson stopped at the Watheroo Observatory for a recomparison of his instrument, No. 28, with the standards of the Observatory. Stops were also made at Carnarvon and Port Hedland, on the Western Australian coast, to reoccupy repeat-stations.

L. A. Richardson, of the Aerial, Geological, and Geophysical Survey of Northern Australia, using magnetometer-inductor 18, occupied six stations in the Northern Territory of Australia, namely, Taylor's Crossing, Barrow Creek, Ryan's Well, Alice Springs, Daly Waters, and Newcastle.

The usual control-observations for the records obtained at the Watheroo Magnetic Observatory were maintained.

North America. Maintenance of International Magnetic Standards of the Department was continued in cooperation with the United States Coast and Geodetic Survey, at the Cheltenham Magnetic Observatory, where CIW sine-galvanometer 1 and CIW Schultze earth-inductor 48 were used as standards for horizontal intensity and inclination.

South America. Secular-variation data were obtained by the control-observations made regularly at the Huancayo Magnetic Observatory. A compilation of magnetic declination observed by the Department was supplied for use of the Argentine Aviation Service.

OBSERVATORY-WORK

Johnston continued in charge of the Section of Observatory-Work. The magnetic reductions and compilations were maintained with the assistance of McNish, Ledig, Scott, and Miss Balsam. Wait and Torreson made excellent progress in the reduction and tabulation of the atmospheric data in conductivity and potential-gradient from both observatories. The members of the staff engaged at the observatories are mentioned in the respective reports.

The observatories at Huancayo (Peru) and Watheroo (Western Australia) continued the extensive geophysical program. Both obtained continuous records of the magnetic elements and magnetic activity was very marked as the peak of the sunspot-cycle was reached during the year. At Huancayo during the exceptionally violent magnetic storm of April 16, 1938, the remarkable range of 1350 gammas occurred in horizontal intensity. This severe storm was completely recorded since an *H*-variometer of low sensitivity had fortunately been placed in operation in June 1937. The height of the ionosphere was continuously recorded at both observatories. Until November 1937 at Huancayo and May 1938 at Watheroo the records were obtained with a fixed-frequency apparatus at 4800 kc/sec with manual-controlled multifrequency observations twice a week. After the dates mentioned the ionospheric records were obtained with automatic multifrequency

equipment, developed in the Department, capable of continuous operation. A frequency-range of 516 to 16,000 kc/sec is completely covered every fifteen minutes. In the short time that the multifrequency equipment has been operating a large amount of valuable data has been accumulated.

Observations in atmospheric electricity, meteorology, and earth-currents were obtained at both observatories. They also made daily observations, weather permitting, with the Hale spectroheliometer at stated times so as to tie in with the solar-disturbance program of the International Astronomical Union for worldwide continuous observations of the Sun. Both observatories continued to send weekly reports by radio of half-day magnetic activity to assist the Department in its preparation of the American magnetic character-figure. Huancayo in addition obtained continuous records with a three-component seismograph and a Compton precision cosmic-ray meter.

Cooperative work was continued with other observatories. The MacGregor Arctic Expedition established a magnetic observatory near Reindeer Point, at Etah, Greenland, using materials and apparatus supplied by the Department. The cooperative program in atmospheric electricity and earth-currents was maintained at Tucson, Arizona, with the assistance of the United States Coast and Geodetic Survey and Bell Telephone Laboratories. With the help of the Department of Scientific and Industrial Research of New Zealand, the atmospheric-electric observations were continued at Apia Observatory, Samoa. The Department supplied forms for observatory- and field-work to the magnetic observatory at Cape Town, South Africa. Cheltenham Magnetic Observatory operated the CIW vertical-intensity inductometer during the year and utilized the Department's sine-galvanometer and standard Schulze earth-inductor for standardizations in horizontal intensity and inclination, respectively.

OPERATIONS AT OBSERVATORIES

The operations during the report-year at the observatories of the Department and at observatories with which the Department cooperated are summarized below.

Watheroo Magnetic Observatory, Western Australia. The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 52' 6''$ east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was operated continuously with only a few hours loss of record caused by the lamp having burned out.

Scale-value determinations for the horizontal-intensity variometer, using the deflection-method, were made once each month and the value has remained remarkably constant throughout the year. Vertical-intensity scale-value observations were made daily by the electrical method. The monthly mean scale-value for both the horizontal and vertical components of the Earth's field for the calendar year 1937 are shown in table 1.

The La Cour rapid-running magnetograph was in continuous operation with the exception of short periods from time to time when the driving mechanism failed, when adjustments were necessary, or when the light failed. Scale-value determinations by the electrical method were made monthly as in previous years and in the case of the *H*-instrument were fairly constant. Some fluctuations occurred in the scale-value of the *Z*-variometer, the values tending to increase toward the middle of the year and

TABLE 1. *Scale-values of magnetographs, Watheroo Magnetic Observatory, 1937*

Month	Scale-values in γ/mm			
	Eschenhagen		La Cour	
	<i>H</i> (reduced to base-line)	<i>Z</i> (means daily values)	<i>H</i>	<i>Z</i>
January.....	2.35	4.13	4.67	2.64
February.....	2.36	4.14	4.64	2.82
March.....	2.34	4.18	4.64	2.80
April.....	2.36	4.29	4.59	2.92
May.....	2.36	4.42	4.60	3.06
June.....	2.35	4.26, 3.74	4.60	3.46
July.....	2.36	3.73	4.59	2.94
August.....	2.36	3.69	4.65	3.11
September.....	2.35	3.77	4.67	3.28
October.....	2.36	3.82	4.59	3.09
November.....	2.37	3.96, 3.28	4.38	2.70
December.....	2.36	3.34	4.45	2.84

dropping back again toward the close of the year. The values for both variometers, as derived from the monthly determinations, are given in table 1.

The Mitchell vertical-force inductometer was kept in operation until, on instructions from the office, it was discontinued December 31, 1937. The galvanometer-sensitivity and scale-value were determined once each month. Toward the close of the year there were more or less frequent stoppages of the driving clock and the record for this period is somewhat fragmentary.

Continuous records of earth-potentials for derivation of diurnal variation of earth-currents were made over the system of electrodes as described in previous reports. A few scattered days were lost but the total loss of record was negligible. Pending the outcome of the result of examination of the record from the new electrode *R'*, which was installed during August 1936, complete scalings for the short east-west line were continued.

Air-potentials have been recorded continuously by means of the standard potential-gradient apparatus as in former years and the usual monthly "reduction-factor" determinations have been made. The mean value, 1.10, agrees well with those determined in earlier years.

Positive and negative air-conductivities were recorded and the usual control-observations were made regularly. Table 2 gives preliminary values of the atmospheric-electric elements as recorded in 1937.

The ionospheric equipment operated continuously. Determinations of layer-heights and of critical frequencies were made in accordance with a regular schedule. The fixed-frequency automatic recorder was in continuous operation with the exception of those periods when multifrequency determinations were being made by manual operation. The multifrequency runs were made in accordance with a regular program. Results of preliminary reduction of the observational data were forwarded to Washington at regular intervals, brief reports of the results of these runs, consisting of layer-heights and critical frequencies, having been forwarded by radiograms, frequently on the day the run was made, and largely through station W3AMS at Washington Grove, Maryland, occasional use being made of station W6GHD in California and W3QP in Pennsylvania. Communication-schedules were maintained between the Observatory and Washington through the cooperation of the above-mentioned stations with only infrequent interruptions throughout the year. From

TABLE 2. Preliminary monthly mean values of atmospheric-electric elements, Watheroo Magnetic Observatory, 1937

Month	Number of selected days	Potential-gradient		Air-conductivity, unit 10^{-4} esu			
		Reduction factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January.....	22	1.08	94.7	1.60	1.53	3.13	1.05
February.....	16	1.11	98.4	1.51	1.36	2.87	1.11
March.....	16	1.09	94.3	1.60	1.52	3.12	1.05
April.....	18	1.13	72.6	2.06	1.96	4.02	1.05
May.....	18	1.12	70.2	2.17	1.89	4.06	1.15
June.....	21	1.22	73.6	2.22	1.94	4.16	1.14
July.....	27	1.09	70.0	2.47	2.19	4.66	1.13
August.....	25	1.14	78.6	2.07	1.80	3.87	1.15
September.....	24	1.04	85.6	1.94	1.68	3.62	1.15
October.....	16	1.04	90.4	1.72	1.52	3.24	1.13
November.....	21	1.00	90.9	1.61	1.49	3.10	1.08
December.....	21	1.10	107.2	1.57	1.64	3.21	0.96
Total and means.	245	1.10	85.5	1.88	1.71	3.59	1.10

July 1, 1937, to June 30, 1938, some 300 messages dealing with scientific results were sent from the Observatory to the office. Magnetic character of days was reported to the office weekly by this means.

After some changes relative to facility of handling of the Hale spectrohelioscope and after some experimental work in October 1937, this instrument was regularly used beginning November 1. Observations were made following the international program covering this work and the records and summarized report were forwarded to the office at the close of each month.

The usual meteorological observations, including sunshine-records, nuclei-count, etc., were made daily and all the self-recording meteorological instruments were kept in continuous operation. Data were supplied monthly to the Commonwealth Weather Bureau in Melbourne as in former years.

At the close of the calendar year 1937 the tabulation and reduction of observatory-data were well in hand.

A summary of the results of magnetic observations obtained during the year indicates that conditions are very similar and changes taking place are approximately of the same order as those indicated in previous reports. The preliminary mean values of magnetic elements for all days of 1937, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $-3^{\circ} 31'8$; horizontal intensity, 0.24676 CGS unit; vertical intensity, -0.51445 CGS unit; and inclination, $-64^{\circ} 22'5$. These results indicate annual changes as follows: declination, $+5.4$; horizontal intensity, -1 gamma; vertical intensity, -33 gammas; and inclination, $-0'9$.

The grounds, buildings, and equipment were kept in order and necessary repair work was done as occasion demanded. An extra roof has been built over the ionospheric laboratory as a means of protecting the equipment from the intense heat of the Australian summer. The attic room in the main quarters was insulated and re-finished, making it much more comfortable and convenient.

Early in April 1938 the new ionospheric equipment, consisting of a multifrequency recorder, was received from Washington. By June 30, 1938, the installation of this

new equipment was completed and records were being made using low antenna. Further calibrations will be made when the high antenna is erected.

Green continued as Observer-in-Charge. Seaton continued as first assistant and in charge of the ionospheric work and communications, though for the last half of the report-year a large part of this work was done by T. K. Hogan, who had been in training throughout the year 1937. Junior observers L. S. Prior and Noel G. Chamberlain have become quite proficient in the various activities of the Observatory and, assisted by Seaton during the last half of the year, made excellent progress in the tabulation and reduction of the observatory-results. C. H. George as mechanic gave excellent service and his work and attention to duty is especially noted. Leslie Aitchison was temporarily engaged as carpenter from November 1937 to June 1938. L. V. Berkner arrived at the Observatory April 10, 1938, to take charge of the installation of the new ionospheric equipment.

The support and cooperation of various State and Commonwealth departments have been continued and are hereby gratefully acknowledged. We are especially indebted to G. A. Scott, Senior Radio Inspector of the Commonwealth Radio Department, for his interest and kindly assistance in the matter of obtaining permission to operate the new multifrequency equipment. Particular mention should be made of the Department of Trade and Customs of the Commonwealth of Australia for kindness and assistance in the matter of importation of equipment. The various officials of the Customs Department of Western Australia have been most helpful in the matter of handling our importations. We are greatly indebted to Professor A. D. Ross of the University of Western Australia for his interest, advice, and assistance with matters pertaining to the Observatory at various times throughout the year.

Huancayo Magnetic Observatory. The Observatory is situated in latitude $12^{\circ} 02' 7''$ south and longitude $75^{\circ} 20' 4''$ west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level.

F. T. Davies was Observer-in-Charge through the year. W. E. Scott was first assistant until September 23, 1937, when he returned to Washington. H. E. Stanton continued as observer through the year. W. Culmsee joined the staff from the Watheroo Observatory on September 1, 1937. H. W. Wells returned to the Observatory on October 8, 1937, as first assistant. T. Astete and A. Macha continued as clerical assistants during the year.

Two magnetographs, one an Eschenhagen, the other a La Cour rapid-run type, were operated continuously. Control of base-lines was obtained by weekly absolute magnetic observations. Scale-values for horizontal intensity and vertical intensity of the La Cour magnetograph were determined electrically once each month. Scale-values for declination and horizontal intensity of the Eschenhagen magnetograph were determined electrically once each week. The vertical intensity scale-value of the Eschenhagen magnetograph was determined electrically three times each week. In addition to the three Eschenhagen variometers, an additional La Cour H variometer was operated at low sensitivity, recording on the Eschenhagen magnetogram. Monthly reports of the more important magnetic disturbances were sent to Washington.

Air-potentials were recorded with standard potential-gradient apparatus and scale-values were determined weekly until December 1937, and biweekly thereafter. Reduction-factors were determined monthly by comparison with potentials measured on open level ground until October 1937 and quarterly thereafter.

Positive and negative air-conductivities were recorded continuously. Scale-values were measured weekly during 1937 and once every two weeks from January 1, 1938.

Earth-current potentials were recorded by a Leeds and Northrup apparatus. Two separate systems of north and south, east and west electrodes were used. Lightning caused occasional stoppages of the apparatus.

Two horizontal-component Wenner-type and one vertical-component Benioff-type seismographs were in continuous operation. Analyses of important seismic disturbances were made and transmitted by radio to Washington.

A Compton-Bennett cosmic-ray meter recorded cosmic-ray intensities during the year. In April 1938 the panel of this meter was changed to allow of greater facility in getting at the batteries and connections. The hourly-zero relay was changed also.

Visual observations of the Sun were made daily with the Hale spectrohelioscope whenever conditions permitted. The assigned periods of observation for this Observatory are 15^h 30^m to 16^h 00^m and 16^h 30^m to 17^h 00^m GMT. Monthly reports of spectrohelioscopic observations were sent to Washington.

Automatic recording of ionospheric heights was maintained during the year. Until October 29 this was done by the older equipment functioning at a fixed frequency, with regular series of manually operated varying-frequency tests to supplement the records. A new multifrequency automatic recorder was installed in place of the fixed-frequency recorder during November to December 1937. The multifrequency apparatus, with a few minor adjustments, has functioned well since installation. Tabulations of critical frequencies and heights for the various layers were made monthly as well as analyses of the data. Quarterly reports on ionospheric conditions were sent to Washington.

Observations of barometric pressure, maximum and minimum temperatures, relative humidity, rainfall, cloudiness, wind-direction, and wind-velocity were made daily at 8^h 75° west meridian time. Measurements of condensation-nuclei were made daily at the same hour. Continuous records were obtained with barograph, thermograph, hygrograph, anemograph, and sunshine-recorder. Computations of and tabulations of magnetic, atmospheric-electric, earth-current, ionospheric, and meteorological studies were kept current, the traces and tabulations being forwarded to Washington monthly, together with seismograms and spectrohelioscopic records. A new recording micro-barograph, purchased from Negretti and Zambra of London, was installed in the Atmospheric-Electricity Building in March 1938. The standard barometer and ordinary barograph were moved from the office to the Atmospheric-Electricity Building in March. A thermograph is in continuous operation in this

TABLE 3. *Preliminary monthly mean values of atmospheric-electric elements, Huancayo Magnetic Observatory, 1937*

Month	Number of selected days	Potential-gradient		Air-conductivity, unit 10^{-4} esu			
		Reduction factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January.....	15	1.15	50.5	3.55	3.48	7.03	1.02
February.....	11	1.16	55.4	3.62	3.44	7.06	1.05
March.....	10	1.15	45.0	4.31	4.21	8.52	1.02
April.....	10	1.17	51.4	3.60	3.59	7.19	1.00
May.....	23	1.16	47.6	4.43	4.49	8.92	0.99
June.....	21	1.19	48.6	4.74	4.83	9.57	0.98
July.....	23	1.20	53.4	4.35	4.42	8.77	0.98
August.....	20	1.14	48.1	3.94	3.97	7.91	0.99
September.....	12	1.14	45.8	4.86	4.83	9.69	1.01
October.....	20	1.14	58.6	3.50	3.56	7.06	0.98
November.....	10	.....	48.1	4.49	4.22	8.71	1.06
December.....	14	.....	47.3	4.81	4.95	9.76	0.97
Total and means.	189	1.16	50.0	4.18	4.17	8.35	1.00

room also. The micro-barograms were scaled and tabulated monthly. Tabulations of barometric pressure, wind-direction, wind-velocity, and sunshine, together with summaries of the meteorological data taken at 8^a daily, were forwarded each month to the Servicio Meteorológico Nacional del Perú and also, by request, to the Centro Geográfico Departamental de Junin.

Preliminary mean values of the magnetic elements for all days of 1937 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $+7^{\circ} 08'3$; horizontal intensity, 0.29593 CGS unit; vertical intensity, $+0.01165$ CGS unit; and inclination, $+2^{\circ} 15'3$. The preliminary values for the annual changes in the magnetic elements, based on these values and on the *final* values for 1936, are: $-3'3$ in declination; -16 gammas in horizontal intensity; $+15$ gammas in vertical intensity; and $+1'8$ in inclination.

Preliminary monthly mean values of the atmospheric-electric elements are given in table 3. The mean value, 1.16, of the reduction-factor for potential-gradient records agrees closely with previous values, which for the years 1934, 1935, and 1936 were 1.16, 1.18, and 1.17, respectively. There were 189 selected days for which the atmospheric-electric elements were derived during the year. The preliminary mean value of potential-gradient for 87 days during the dry season was 49.4 volts per meter and for 102 days in the wet season was 50.3 volts per meter.

Many courtesies were extended the Observatory and its staff by the governmental officials and departments of Peru and by local provincial and municipal authorities. The success of the year's work has also been furthered by the cordial attitude of the Ambassador and the Consul-General to Peru of the United States.

COOPERATION WITH OTHER OBSERVATORIES

Apia Observatory, Western Samoa. Cooperation of the Department with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ west) in the fields of atmospheric electricity and terrestrial magnetism was continued. The program of work at the Observatory also includes seismology and meteorology.

The work in terrestrial magnetism consisted of absolute measurements of horizontal intensity, declination, and inclination, together with the continuous operation of autographic instruments for recording the variations in horizontal intensity, declination, and vertical intensity.

The instruments used for absolute observations were CIW magnetometer 9 (on loan through the courtesy of the Department of Terrestrial Magnetism) and Schulze earth-inductor 2. The autographic records were obtained by means of two Eschenhagen variometers for horizontal force and declination and a Godhavn balance for vertical intensity. The continuity of the records was interrupted for a period of three months, commencing in July 1937, when the roof of the Gauss House was under repair. Minor interruptions were caused by the appearance of slender fibers (thought to be fungoid growth) in the Eschenhagen variometers.

The revision of the declination-measurements for the period 1932-1934, rendered necessary by the discovery in 1935 of a defect in the old Tesdorpf magnetometer, was completed.

Potential-gradient measurements with the Benndorf electrometer were continued during the year. Absolute observations during the dry season of 1937 showed that the fall of a tree in the vicinity of the potential-gradient building had not affected the value of the reduction-factor. The leak-free potentiometer-method due to Gish and Sherman has been used, since March 1938, in experiments to determine the reduction-factor. The value 1.00 has been adopted for this factor as in previous years.

During 1937 there were 89 zero-days with a mean value of 123 volts per meter.

The mean values, expressed in volts per meter, of the potential-gradient were as follows: January, 120; February, no zero-days; March, 97; April, 113; May, 115; June, 127; July, 133; August, 121; September, 124; October, 122; November, 130; December, 147.

The seismographs, which were originally installed at Apia more than thirty years ago, were maintained in use. Some slight modifications of design which were introduced in July 1937 improved the scope of the records. During the year ended June 30, 1938, 244 seismic disturbances were recorded.

The routine work in meteorology comprised surface-observations made twice a day and frequent measurements of upper winds. Climatological summaries were also prepared and synoptic charts of the weather in the southwest Pacific Ocean were plotted every day. Storm-warnings were issued when necessary with the general collective broadcast of weather-reports from the Apia Radio Station.

TABLE 4. *Meteorological summary, Apia Observatory, 1937*

Month	Pressure	Temp.	Rainfall	Humidity (9 a.m.)	Sunshine	Wind
	inches	°F	inches	per cent	hours	miles/hr
January.....	29.744	80.2	15.20	80	220.7	7.4
February.....	29.779	80.3	15.85	81	151.5	7.6
March.....	29.769	79.3	16.15	81	187.2	5.9
April.....	29.814	80.0	9.41	80	212.2	6.3
May.....	29.872	79.0	15.59	77	218.0	7.5
June.....	29.867	78.8	0.65	76	245.7	7.9
July.....	29.861	79.0	2.02	76	259.7	7.8
August.....	29.861	78.8	6.26	78	223.4	11.0
September.....	29.902	78.4	5.46	74	223.2	6.9
October.....	29.866	79.2	9.28	77	205.5	8.4
November.....	29.799	79.7	4.56	74	225.1	5.8
December.....	29.767	79.7	11.17	76	192.5	5.4
Mean or total.....	29.825	79.4	111.60	77	2564.7	7.3

J. Wadsworth, who had been the Director since September 1, 1930, resigned in June 1938 and left Apia on June 9. H. B. Sapsford assumed control as Acting Director. J. M. Austin, C. W. Tremewan, and A. B. F. Ayers joined the professional staff of the Apia Observatory during the year.

Tucson Magnetic Observatory, United States. Observer-in-Charge J. Hershberger with the assistance of R. F. White, both of the staff of the United States Coast and Geodetic Survey Tucson Magnetic Observatory, operated the Department's apparatus for recording atmospheric potential-gradient and positive and negative air-conductivities. Mrs. G. Dewey, employed by the Department on part-time basis at the Observatory, reduced these records. Nine observations were made of the potential-gradient reduction-factor, giving a mean value of 1.23 for reduction of observed values to volts per meter. Table 5 summarizes the monthly and annual values of the atmospheric-electric elements.

Registration of earth-currents was continued using the new electrodes installed in the last report-year. The Bell Telephone Laboratories specially leased a line for connection to the Wilcox electrode. Earth-current activity was specially marked during the sunspot-maximum prevailing, and in consequence much trace was lost. Unfortunately a galvanometer of low sensitivity was not available for the recording.

Magnetic Branch, Trigonometrical Survey, Union of South Africa. Cooperation with the Magnetic Branch of the Trigonometrical Survey of the Union of South

TABLE 5. Preliminary monthly mean values of atmospheric-electric elements, Tucson Magnetic Observatory, 1937

Month	Number of selected days	Potential-gradient		Air-conductivity, unit 10^{-4} esu			
		Reduction factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January	24	1.22	65.3	1.77	1.58	3.35	1.12
February	23	1.24	57.7	2.18	1.61	3.79	1.35
March	24	.....	48.6	2.17	2.18	4.35	1.00
April	24	1.25	46.9	2.15	2.28	4.43	0.94
May	25	1.29	45.0	2.45	2.64	5.09	0.93
June	25	1.22	52.2	2.66	2.82	5.48	0.94
July	16	1.20	48.7	2.52	2.38	4.90	1.06
August	20	1.22	46.8	2.44	2.25	4.69	1.08
September	23	.....	44.4	2.57	2.30	4.87	1.12
October	30	1.20	44.7	2.66	2.39	5.05	1.11
November	27	.....	50.9	2.87	2.33	5.20	1.23
December	29	1.27	54.4	2.31	2.04	4.35	1.13
Total and means.	290	1.23	50.5	2.40	2.23	4.63	1.08

Africa was continued in the operation of the Cape Town Magnetic Observatory. A CIW magnetometer-inductor is on loan for control of magnetograms. Dr. A. Ogg, Magnetic-Survey Adviser, was supplied with details and particulars regarding field- and observatory-work.

Royal Alfred Observatory, Port Louis, Mauritius, Indian Ocean. The loan of equipment, including a CIW marine inductor and galvanometer for control of vertical-intensity records at the Royal Alfred Observatory, Mauritius, was continued.

College, Alaska. Professor E. H. Bramhall continued work in the laboratory preparing equipment for recording of ionospheric conditions. The volume "Auroral research at the University of Alaska, 1930-1934" (volume 3 of the miscellaneous publications of the University) was edited and seen through the press by Fleming in an edition of 1000, of which 575 copies have been sent interested investigators and organizations.

Etah Magnetic Observatory, Greenland. The MacGregor Arctic Expedition was at winter base at Etah, Greenland, from September 1937, and the whole party was busily engaged in prosecuting the magnetic, meteorological, auroral, and exploratory programs. The CIW magnetic station of 1908 and 1923 at Reindeer Point, near Etah, was reoccupied to determine secular variation.

The non-magnetic observatory with its walls, roof, and floor thickly covered with Balsam Wool for insulating purposes was completed by September 15, 1937, and the magnetographs were installed one week later by Roy Fitzsimmons, magnetician of the Expedition. Since then continuous records of the magnetic elements have been obtained. (The station was dismantled at midnight July 5, 1938.) The Expedition sent by radio weekly reports of observed magnetic activity to the Department of Terrestrial Magnetism in Washington, D. C., and these were broadcast weekly from Washington and were published weekly in the *Science Service Research Aid Announcements*.

Surface meteorological observations were obtained at hourly intervals. Eight o'clock morning and evening reports were sent to the United States Weather Bureau giving barometric pressure, pressure characteristic, weather, wind-direction and wind-velocity, observed air-temperature, and maximum and minimum temperatures. Pilot balloons were flown twice daily, weather permitting. Unusually warm weather

prevailed, the lowest average temperature being -30° C. Winds were unusually high. The auroral program consisted of visual observations and 45 photographs were obtained. The wind-driven generators for charging the storage-batteries proved quite efficient.

The weather was not very satisfactory for flying; however, Commander Schlossbach made two successful reconnaissance-flights. In the first he flew alone over the supposed Crocker Land area and saw no signs of this land. In a later flight Ellesmere Island was thoroughly explored from the air and some unusually high mountain peaks were discovered.

Owing to the unusually mild winter solid ice did not form in Smith Sound, and therefore many sledge-trips were made in northern Greenland. Roy Fitzsimmons and Paul Furlong finally succeeded in crossing to Cape Sabine in April and made magnetic observations. The Expedition plans to return to New York in the summer of 1938.

Cheltenham Magnetic Observatory, United States. Cooperation at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was continued. CIW instruments used for maintaining standards and for test included the following: Sine-galvanometer 1 and earth-inductor 48 for control of standards in horizontal intensity and inclination; permivar vertical-intensity induction-variometer for test of method; Compton-Bennett precision cosmic-ray meter 1 for automatic recording of cosmic-ray intensity. Observer-in-Charge Ludy and G. Hartnell of the staff of the Observatory gave generously of their time and skill in these cooperative endeavors. The National Bureau of Standards carefully recalibrated the standard cells and potentiometer at the Observatory to check upon their behavior in connection with sine-galvanometer performance; as in the previous year the resulting correction to computed values because of slight change in calibrations is quite small, the total correction being only -0.5 gamma.

Meteorological Office, Wellington, New Zealand. CIW Aitken nuclei-counter 7 was on loan throughout the report-year to Dr. Edward Kidson, Director of the Meteorological Office at Wellington, New Zealand. Summaries of data obtained there by C. G. Green of Dr. Kidson's staff from July 1937 through March 1938 were received.

Stanford University, California. CIW Aitken nuclei-counter 6 was loaned for some six weeks to Professor N. E. Bradbury of the Department of Physics of Stanford University for comparison with and calibration of that Department's newly constructed recording nuclei-counter.

REDUCTION OF MAGNETIC DATA

The Section of Observatory-Work was actively engaged in the reduction of the accumulated magnetic data from the Watheroo and Huancayo observatories. The final revised results of Watheroo for the year 1935 were added to the manuscript of Watheroo data for the years 1919 to 1934. The Huancayo data were completely reduced for the year 1936. Work is now progressing on the current magnetic observations from both observatories.

The new measure of activity in the Earth's magnetic field, the American character-figure C_A , was compiled throughout the report-year. The data were statistically examined and the character-figure was shown to be a precise measure. It represents worldwide magnetic conditions with relatively high fidelity. A close relation exists between the American and international character-figures. A correlation-coefficient of 0.70 was found between this new measure and the radio transmission-disturbance figure

for the circuit, New York to London, of the Bell Telephone Laboratories. Because of this high correlation the information derived from study of variations in terrestrial magnetism over the past century may be applied to problems in radio communication. The American character-figure discriminates very exactly between degrees of magnetic activity on highly disturbed days when radio communication is most affected.

The final values of the magnetic elements for 1936 and the preliminary values for 1937 for all days are shown in table 6.

TABLE 6. *Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based upon magnetograms for all days*

Year	Declination <i>D</i>	Inclination <i>I</i>	Intensity-components					Local magnetic constant <i>G</i>
			Horizontal <i>H</i>	Total <i>F</i>	North-south <i>X</i>	East-west <i>Y</i>	Vertical <i>Z</i>	
WATHEROO MAGNETIC OBSERVATORY								
1936....	3 37.1W	64 21.6S	24677γ	57028γ	24628γ	—1557γ	—51412γ	35634
1937....	3 31.8	64 22.5	24676	57057	24629	—1519	—51445	35645
HUANCAYO MAGNETIC OBSERVATORY								
1936....	7 11.6E	2 13.5N	29609	29631	29376	3708	1150	29615
1937....	7 08.3	2 15.3	29593	29616	29364	3677	1165	29599

REDUCTION OF ELECTRIC DATA

Wait, Torreson, and Miss Balsam continued the reduction of atmospheric-electric records from Watheroo and Huancayo for the 11-year period 1924-1934 and preparation of the results for offset reproduction in publication. Besides the hourly mean values of potential-gradient and positive and negative air-conductivities, the results include electric character-figures and meteorological data. For Tucson only the preliminary compilations of the atmospheric-electric data have been prepared by Mrs. Dewey; final tabulations for publication of these must await completion in 1939 of the material from Watheroo and Huancayo.

Rooney kept current the final reductions of the earth-current records at Watheroo, Huancayo, and Tucson.

OCEANOGRAPHIC WORK

REDUCTIONS OF CARNEGIE DATA

PHYSICAL AND CHEMICAL RESULTS

Final revision of manuscript prepared by Mrs. K. B. Clarke-Hafstad and added discussion of the meteorological results obtained on the *Carnegie* during her seventh cruise were completed by W. C. Jacobs at the Scripps Institution of Oceanography under the supervision of H. U. Sverdrup, re-

search associate. The title of the manuscript is "Meteorological results of Cruise VII of the *Carnegie*, 1928-1929" by K. B. Clarke-Hafstad and W. C. Jacobs. It is planned to publish it as part of volume IV of the series "Results of oceanographic and meteorological work obtained on board the *Carnegie*, Cruise VII, 1928-1929, under the command of J. P. Ault."

BIOLOGICAL RESULTS

Throughout most of the year Graham was occupied at the Hopkins Marine Station, Pacific Grove, California, in a continuation of studies of the dinoflagellates of the *Carnegie* plankton-collections. During June 20 to August 31, 1937, however, he was stationed in Palo Alto at the Division of Plant Biology of the Carnegie Institution of Washington, where manuscript was prepared and frequent use was made of the libraries of Stanford University. Mrs. N. Bronikovski assisted to the end of 1937 in the routine examination of the plankton-samples and in the preliminary sketching of organisms. Mrs. Mary Doudoroff was employed from January 1 as artist and laboratory assistant to prepare maps and drawings and to assist in preparation of lists of species, etc.

The routine examination of the plankton-samples for dinoflagellates was completed for the entire collection. Distributional lists including records of depth and all chemical and physical conditions of the water observed were compiled for 76 species. Ranges of conditions for each species were computed as well as the ranges of surface-temperatures for the record-stations in an attempt to determine the environmental tolerances of each species. Particular attention was paid to the depth-distribution and tables were compiled for each species showing the frequency of sample records for 0, 50, and 100 m.

The report on the thecal morphology and interrelationships of the members of the Peridinales begun last year was completed under the title "Studies in the morphology, taxonomy, and ecology of the Peridinales." It deals with 29 different species and varieties of the order which were examined in considerable detail in connection with skeletal features in order to gain a better understanding of the natural relationships which should underlie the classification of the group. The species studied belong to the following genera: *Goniodoma*, *Ceratocorys*, *Goniaulax*, *Acanthogoniaulax*, *Spiraulax*, *Peridinium*, and *Ceratium*.

In addition to the above report on the interrelationships of the genera of Peridinales, a paper was begun on the distribution of the genus *Ceratium*. This large genus including 57 species has been given particular attention in recent oceanographic expeditions because it is the only genus which is common and at the same time for which there is any approach to a satisfactory classification. In the *Carnegie* studies of this genus a minimum of time was spent on the taxonomy of the group and an attempt made to correlate the distribution of the species with general oceanographic conditions. This work was almost completed during the report-year.

With the completion of the preliminary census of samples it was possible to begin a study of the interrelationships between the distribution of the species and oceanographic conditions in general. This aspect of the study

was applied particularly to the 57 species of the genus *Ceratium* found in the collection. On the basis of the study of these forms a new phytogeographic classification was made. This classification may possibly apply to all oceanic plankton-species. It recognizes only two main groups, namely, tropical and subpolar, in addition to cosmopolitan species. There are no temperate species, that is, no species which occur in intermediate latitudes which are not also found as abundantly either in the tropics or in subpolar regions. The tropical forms vary in their tolerance to subtropical and temperate conditions so that there are intolerant, slightly tolerant, and very tolerant tropical species. The distributional limits of the two main groups are closely correlated with the regions of the subpolar convergence in both the Atlantic and the Pacific.

Considerable evidence of the isolation of the North Pacific waters was accumulated from the distribution of the *Ceratium* species. The subpolar flora at the northern *Carnegie* stations in the Pacific was definitely different from that which is well known to occur in the northern Atlantic and adjacent subarctic waters.

Particular attention was paid the vertical distribution of *Ceratium*. The data of Jörgensen (1920), which he used for the analysis of currents in the Mediterranean, were shown by Nielsen (1934) to indicate a shade flora rather than currents. The *Carnegie* data substantiate the contention of Nielsen that Jörgensen's "winter species" are in truth shade species. Twenty of the 57 *Carnegie* species were found with increasing frequency with increase in depth to 100 m. and are thus shade species; 6 were questionably so. Most of these species were the same as those designated shade species by Nielsen. These forms are particularly adapted for life in dimly illuminated regions and show very definite morphological peculiarities. The advantage of such an adaptation is obviously the ability to utilize the store of nutrient salts in the subsurface levels.

MISCELLANEOUS

Upon request of the Hydrographer of the British Admiralty, details regarding atmospheric-electric instruments and program on the *Carnegie* were supplied for consideration of the proposed work of the *Research*. Details were also supplied the Hydrographer regarding the feathering-propeller design of the *Carnegie*.

Graham took part in the seminars of the Hopkins Marine Station and presented two papers, namely, "Evolution in Ceratia" January 7, 1938, and "On oceanic aspects of *Ceratium*" July 1, 1938.

INSTRUMENT-SHOP

The personnel of the instrument-shop comprised Steiner (in charge), Lorz, Haase, A. Smith, Huff, Mitchell (to January 31, 1938), Fogel (from February 1, 1938), Malvin, and Quade. They are responsible for the design and construction of new equipment and experimental apparatus, and the maintenance of instruments, buildings, and grounds. The more important projects included: equipment for Atomic-Physics Observatory;

ionospheric apparatus; electromagnetic standard instrument; improvements and repairs to shop; packing; and exhibit. Close collaboration was maintained with the various investigators that their problems might be met effectively in the construction of instruments and equipment.

In the Atomic-Physics Observatory a heating system was installed; this necessitated special venting and cut-off valves for use when the tank is in operation under pressure. A water-supply system was installed, together with a spray-system on top of the tank for cooling purposes. Gas and compressed-air lines were extended from the main building with push-button station-controls and pilot-lights for the latter. The necessary electric power and lighting circuits for both direct current and alternating current were installed with suitable remote controls.

The second automatic multifrequency ionospheric equipment was completed for Watheroo. The unit for the Huancayo Magnetic Observatory was shipped and also the one for Watheroo Magnetic Observatory after calibration at Kensington.

Good progress was made on the electromagnetic standard instrument for measuring the Earth's magnetic field; the grinding and lapping of the pyrex cylinder were completed. The coil was wound after developing a satisfactory method of lubrication and wire drawing to give the best wire surface and proper winding tension. After winding, the coil was marked precisely by markings in both horizontal and vertical directions for measurements of final pitch and diameter. A special micrometer with direct reading of one micron for measuring this coil was constructed.

A new rotating mount and shield for electromagnetic measurement of core-samples (after design of Johnson and McNish) were constructed and added to the pier in the Standardizing Magnetic Observatory for electromagnetic measurements. A non-magnetic saw-table with diamond-charged copper saw was built to cut unit-blocks from core-samples and varves for these magnetic measurements.

Miscellaneous items included: a detector-unit and a four-stage amplifier-unit constructed for use at Mount Wilson Observatory by Dr. Wright in investigations of the Moon Committee; adaptation of a 10-second circle and verniers for gravity-apparatus by Dr. Wright of the Geophysical Laboratory; three contact rollers and two spare shafts for the calibrating drum of the conductivity-apparatus at Tucson Observatory; amber insulator and clock contactor for potential-gradient apparatus at Apia Observatory; three idler film sprockets and film-guard plates for light-slit of Millikan-Neher cosmic-ray meters; a special alternating-current demagnetizing device for use in making astatic the newly designed galvanometer magnet-systems of Alnico; repairs and improvements to instruments and equipment for field, laboratory, and observatory; improvements and repairs to buildings and site; packing and forwarding equipment, appurtenances, and supplies.

Steiner prepared an article on the method of producing nonmagnetic castings developed by the Department. This is an important subject since in the manufacture of instruments for making magnetic measurements it is essential that the susceptibility of all materials entering into their construction be negligible. Castings of such materials are difficult to obtain commercially,

for which reason the method of producing sound nonmagnetic castings of copper, bronze, brass, and aluminum was developed in the Department. This procedure has been accomplished by a close control of the melting temperatures, method of purification of the material, and design of the patterns.

MISCELLANEOUS ACTIVITIES

Communications to scientific organizations and universities. Bartels gave weekly lectures at the University of Berlin on "Terrestrial magnetism, earth-currents, and aurora," on "Spherical harmonics in geophysics," and on "Sunspots and their terrestrial effects." Talks were given on "New results about the ionosphere" and "Barometer-readings at fixed hours as material for the computation of lunar atmospheric tides" at the University of Berlin, on "Methods for detecting hidden periodicities in geophysics" at the Dresden Technische Hochschule, and on "Terrestrial-magnetic inferences about solar activity" before the Astrophysical Colloquium at Berlin-Babelsberg. Bartels spent two weeks in October with Chapman preparing manuscript of a textbook entitled "Geomagnetism," of which they are coauthors. Forbush presented a series of six lectures in a course at the National Bureau of Standards on Fourier series in statistical treatment of periodicities.

Active part was taken by members of the staff in meetings of American scientific societies through papers and discussions as indicated below or in the report above. The Department was represented by seven papers in the annual meetings of the American Geophysical Union in April. Fleming and Capello prepared for publication the *Transactions* of the nineteenth annual meeting of that Union (two volumes containing 745 pages). Fleming presented a paper on "Terrestrial magnetism and oceanic structure" in a symposium sponsored by the Union upon the invitation of the American Philosophical Society at Philadelphia in November 1937. He also attended the round-table discussion of that Society in February 1938 on possible economies in conventional and newer methods of scholarly publication, and submitted a "Memorandum on planographic publication from typescript." McNish and Johnston presented a paper at a joint meeting of the American Section of the International Scientific Radio Union and the Institute of Radio Engineers in April 1938 on "The American magnetic character-figure C_A in relation to communication problems." McNish took part as guest-scientist in a radio broadcast May 20, 1938, on "Sunspots and citizens" in the series "Adventures in science" sponsored by the Columbia Broadcasting Company and Science Service. Wait addressed the Engineers' Club of Baltimore in November 1937 on "What about the ions in the atmosphere?"

Several members of the Department's staff contributed or were coauthors in eight of thirteen chapters prepared for volume VIII of the National Research Council's series "Physics of the Earth" entitled "Terrestrial magnetism and electricity," manuscript for which was submitted June 30, 1938, by Fleming as Chairman of the Special Subsidiary Committee. These were: "The Earth's magnetism and magnetic surveys"; "Magnetic instruments"; "Atmospheric electricity"; "Instruments used in observations of atmospheric electricity"; "Earth-currents"; "On causes of the Earth's magnetism and its

changes"; "Some problems of terrestrial magnetism and electricity"; "Radio exploration of the Earth's outer atmosphere"; "Bibliographical notes and selected references."

Conferences and contacts. Gish attended a conference of geologists and geophysicists at Red Lodge, Montana, July 29-30, 1937. He also participated in the Big Horn Basin-Yellowstone Valley Tectonics Field Conference at Red Lodge, August 3-5, 1937.

Creation of a Planning and Project Committee of the American Geophysical Union during the past year has given opportunity for promotion of a number of projects which rightly involve the cooperation of a number of institutions and organizations, in which several of the Department's staff took part.

McNish spent three weeks during July 1937 studying solar phenomena at the Mount Wilson Observatory and conferring with members of the staff on relations between solar phenomena and terrestrial magnetism and on possibilities of closer cooperation between investigators in these fields. He spoke at one of the Observatory's staff-meetings on such relations. He also discussed with Dr. Beno Gutenberg of the Seismological Laboratory in Pasadena the state and constitution of the Earth's interior, and with Drs. Bradbury and Terman at Stanford University processes of ionization and recombination in the ionosphere.

Fleming represented the Institution at the inauguration of Dr. Levering Tyson as President of Muhlenberg College in Allentown, Pennsylvania, October 1 and 2, 1937.

In response to a request from Dr. Jan Blaton, Director of the Meteorological Service of Poland, Gish and Sherman provided drawings and descriptions, in greater detail than has been published, of the apparatus employed for the registration of air-conductivity on the flight of the stratosphere-balloon *Explorer II*. Later Dr. Boleslaw Cynk, Assistant Chief of the Marine Observatory, Gdynia, Poland, who arrived at the Department on June 18 for a stay of three months, was introduced to the methods and technique of atmospheric-electric measurements by Gish and Sherman.

Detailed earth-current data covering a number of violently disturbed periods early in 1927 were prepared by Rooney and forwarded to the Australian Ministry of Posts and Telegraph for use in their investigation of the connection between their operating difficulties and terrestrial electromagnetic disturbances.

Electrical prospecting methods were discussed with a number of visitors, particularly with Messrs. Du Houx and De Magne of the University of Brussels, Belgium, who were interested in the apparatus and technique for making earth-resistivity surveys.

A recorder and accessories were lent to Professor Charles M. Heck of the Physics Department, North Carolina State College of Agriculture and Engineering, University of North Carolina, Raleigh, for use in research on earth-radiation at night.

Suggestions and comments on proposed establishment of departments of geophysics were made on request to the Department of Physics of the State

University of Iowa and to the Department of Geology of the University of Virginia.

Staff-meetings and colloquia. Afternoon biweekly staff-meetings were held from November 1937 to April 1938. These meetings were devoted to reports on recent progress in topics bearing on problems of the Department by members of the staff and by invited guests.

A seminar on "The propagation of radio waves in the ionosphere," in charge of Dr. H. G. Booker, was held every Thursday evening beginning October 14, for ten meetings.

Members of the staff took part in the staff-meetings of the National Bureau of Standards and the meetings of the Washington Physics Colloquium at George Washington University.

Exhibit. Recent investigations of the radio and magnetic effects produced by eruptions in the solar chromosphere formed the basis for the Department's contribution to the annual exhibit of the Institution held in December. Appropriate devices showed in successive steps (1) the outburst of a solar eruption, (2) the cessation of radio reflections from the ionosphere, and (3) sudden displacement of the compass. A series of transparencies showed the interpretation of the effects and the relation of the investigation to particular problems in terrestrial magnetism. McNish and Torreson took part with Nicholson of Mount Wilson Observatory in presenting a radio broadcast over the Columbia network December 11, 1937, relating to the exhibit on "Sunspots, radio, and magnetism." McNish also lectured during the exhibit on "The Earth's atmosphere responds." Following the exhibition in Washington the Department's exhibit was shown in the Museum of Arts and Sciences in Baltimore and in the Museum of Science and Industry in New York.

Institution activities. Members of the staff took active part in special committees of the Institution on physical sciences, coordination of cosmic-ray investigations, building, lectures, exhibit, radio, application of results in the physical sciences, and Central American volcanological investigations.

William Shepherd of the Division of Historical Research was instructed by mail in astronomical and magnetic observations, and radio equipment for his work in Guatemala was overhauled; his results for astronomical position were revised. Data regarding positions of three of the Division's stations in Guatemala were supplied the Fairchild Aerial Surveys for use in the aerial contract of the Division.

Library. During the report-year, the library has continued to acquire copies of all new publications dealing with terrestrial magnetism and electricity, as well as publications relating to investigations in other fields conducted by the Department. Accessions to the library during the report-year numbered 610, bringing the total number of accessioned books and pamphlets to 24,755. The practice was continued of carding, classifying, and filing in the index all important articles of interest in current scientific journals, of which about 100 are regularly received; hence the new accessions represent only a small percentage of the total additions to our index, which becomes each year progressively more valuable for reference-purposes. An outstanding addition to our library is the recently acquired complete set of the *Bei-*

blätter zu den Annalen der Physik und Chemie from its beginning in 1877 to 1911, thus completing the Department's set. Accordingly the last quarter of the last century, for which no abstract-references were available in our library, is now covered by this useful publication.

Librarian Harradon continued to take part in editing contributions to the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, particularly the manuscripts in foreign languages. Notes of current interest and abstracts of publications were prepared as well as the quarterly annotated lists of recent publications which appear in each number of the Journal. Translations of letters and documents were made as necessary; many of these pertained to international scientific organizations. Help was given in preparation of the preliminary program of the seventh triennial assembly of the International Union of Geodesy and Geophysics.

A list of papers by the members of the Department's staff compiled by the librarian for 1937 shows that the total number of such publications on December 31, 1937, was 1694. Separates of papers were distributed regularly to institutions and individuals on the Department's mailing list. The service of the International Exchange of the Smithsonian Institution was again utilized, effecting considerable economy as on previous occasions.

Dove continued in charge of the general files of the Department, typed many reports and manuscripts, and cared for storage and distribution of the departmental reprints.

As heretofore, the facilities of the library were extended to investigators and students from various institutions and governmental bureaus. Inter-library loans were made with other libraries and cordial and reciprocal relations were maintained, particularly with the Library of Congress, to the mutual advantage of all concerned.

Office administration. M. B. Smith, administrative assistant, with the assistance of Moats and Singer, looked after the numerous details of accounts, audits, reports, and correspondence. Capello, secretary and property clerk, had charge of shipments and inventory and prepared many manuscripts. Numerous charts, drawings, and sketches required for papers, lantern-slides, and exhibits were prepared by Hendrix. Photographic work to show development of equipment and apparatus and details of construction was done by Ledig, who also solved a number of photographic problems arising in instrumental design.

ANTHROPOLOGY

Aberle, Sophie D., United Pueblos Agency, Albuquerque, New Mexico.
Studies of the growth and development of Pueblo Indian children. (For previous reports see Year Books Nos. 34, 36.)

These studies, which were begun by Dr. Aberle a few years ago, have been continued with aid from the Carnegie Corporation of New York. Additional studies have been undertaken in cooperation with the research program of the Carnegie Institution of Washington and activities of the United States Office of Indian Affairs and other agencies.

The two major lines of activity which have been followed throughout the past year are analysis of the current demographic records of the Pueblo area, by Dr. Jack Watkins of the Department of Public Health of Yale University, and analysis of the detailed anthropological measurements collected during the past six years by Elizabeth Pitney.

POPULATION AND VITAL STATISTICS

Vital history of San Juan Pueblo—To the analysis of the San Juan Parish records has been added a chapter on present-day mortality in San Juan which includes a complete life table and permits comparison with white and Negro mortality.

Vital statistics of the pueblos—An analysis of the demography of the pueblos as a whole is now under way. Tables showing trends of mortality and natality, sex and age differences, and population composition are being prepared. This information will throw light on the rate of increase in the Pueblo population.

DIMENSIONAL GROWTH AND DEVELOPMENT

Detailed anthropometric measurements—The accumulation of complete records, embodying some 50 measurements upon the same group of 200 Pueblo and Hopi children, 11 to 15 years old, was continued this year with the addition of the sixth annual series of measurements. It was possible to take the measurements this summer after the close of school through the cooperation of the Indian Service, which provided transportation and the assistance of day school teachers necessary for bringing the children to central points for examination.

Statistical analysis of heights and weights—The analysis of the 3000 measurements of children 6 to 16 years old begun at the University of Minnesota has been continued at Yale. Two main objects have been pursued: the discovery of a reliable and sensitive method for determining rate of growth and the finding of a device for discovering possible differences in dimensional size among children from different pueblos.

For the purpose of determining the rate of growth at different age periods and the age at onset of the prepubertal spurt in growth, actual annual gains in height and weight have been computed from all available repeated measurements. It has been shown with long-time serial data that the

annual gains determine the rate of growth with greater statistical reliability than the differencing of annual successive means of height and weight.

In addition, the test of goodness of fit has been applied to the dimensional size of children in each separate pueblo group and these results compared to the distribution in the group as a whole.

ASTRONOMY

Boss, Benjamin, Harry Raymond, and Isabella Lange, Dudley Observatory, Albany, New York. *Special studies based upon utilization and interpretation of materials in the General Catalogue of Stars.*

During the past year the material contained in the *General Catalogue* has undergone several processes in preparation for research growing out of it, and four investigations have been completed. The first constitutes a discussion of solar motion, precessional corrections, and galactic rotation by Ralph E. Wilson and Harry Raymond. In their treatment of the subject solutions were made of the material arranged according to magnitude, amount of proper motion, and spectral type in order to determine their effects upon the problem. The constants of galactic rotation were found to be $-0''.25 \pm 0''.03$ for B/4.74 and $+0''.26$ for A/4.74. The precessional corrections were $\Delta p = +0''.94 \pm 0''.044$ and $-\Delta e - \Delta \lambda = -1''.10 \pm 0''.045$, centennial, indicating corrections to Newcomb's tables of precession in right ascension $-0''.016 + 0''.025 \sin \alpha \tan \delta$, and in declination $+0''.38 \cos \alpha$. The question of solar motion has always presented difficulties. The *General Catalogue* proper motions indicate a change in the position of the apex amounting to about 4° northward per unit change in visual magnitude, as fainter stars are employed for the solution. There are also pronounced differences between groupings according to spectral type. The causes of these discrepancies will be sought in a later investigation, but it is evident that the proportion in which large skew velocities are included must be a contributing factor.

Mr. Raymond has extended the discussion to the *General Catalogue* stars with centennial proper motions exceeding $40''$, in two groups, proper motions from $40''$ to $80''$, and over $80''$. The size of the solar motion appears to increase very nearly in proportion to the mean proper motion of the stars used to determine it, strongly suggesting that these stars appear to move fast because they are near rather than because of large real velocities. There is no northward trend of the apex, but instead an eastward trend as proper motions increase. This amounts to 18° between the extreme groups, those with motions less than $10''$, and those exceeding $80''$.

In order to establish a criterion whereby parallaxes might be determined for those stars in the *General Catalogue* for which no trigonometric or spectroscopic parallaxes have been published, a system of hypothetical absolute magnitudes has been formed by Benjamin Boss, utilizing H and its adjustment to M. In the process of adjusting, an attempt has been made to correct for the skew distribution of the absolute magnitudes in the groups treated. The hypothetical absolute magnitudes appear to compare favorably with those determined from observation. Thus reasonably accurate parallaxes are available for some 25,000 stars to add to the 8,000 previously determined.

Stellar luminosities are an important part in many astronomical investigations. Consequently luminosity curves have been constructed by Benjamin Boss and Miss Isabelle Lange for all the stars contained in the *General Catalogue* utilizing the H function as the unit of luminosity and treating the

material by Harvard spectral types. The resulting curves show rather definitely that among the stars of the *General Catalogue* there are but two significant luminosity distributions, corresponding to main and giant sequence stars. There was absolutely no evidence of the so-called intermediate class, whose supposed existence was apparently due to the distribution of accidental error in observed parallaxes. Even F-type stars which have previously offered difficulties are well represented by a single distribution. There is however some slight evidence of a supergiant system in the case of KO stars, but the lack of any trace of such a class in adjoining types casts some doubt upon its reality. There is likewise a possible trace of supergiants among the F-type stars, but if real their numbers are relatively insignificant. The known existence of a white dwarf class among stars fainter than those included in the *General Catalogue* demonstrates that we should be cautious about closing the door to other possible luminosity distributions.

Roy, A. J., Dudley Observatory, Albany, New York. *Completion of reductions of observations of the late A. S. Flint of Washburn Observatory, comprising the Madison Catalogue of 2786 stars*, in cooperation with **Joel Stebbins**, Research Associate.

Shortly after the appearance of the Boss *Preliminary General Catalogue*, published by the Carnegie Institution of Washington in 1910, a cooperative arrangement was made between the Dudley and Washburn observatories to observe certain fainter stars for which modern positions were needed for the Boss *General Catalogue*. The Dudley work was carried through and published in the *Albany Catalogue* but the reductions of the Washburn observations made by Albert S. Flint from 1912 to 1919 were not finished at the time of his death in 1923. The completion of these reductions was undertaken by the Department of Meridian Astrometry of the Carnegie Institution, but for various reasons it was found that the inclusion of the Madison results would have unduly delayed the *General Catalogue*.

Inasmuch as considerable progress had been made on the Washburn material under the direction of Arthur J. Roy, the task was assigned to him for post-retirement service to complete and prepare for publication. He has devoted full time to this project from February 1936 to August 1938. In addition considerable routine computing was done by students at the Washburn Observatory under the supervision of C. M. Huffer.

There were 9900 observations of 2786 stars. The internal agreement of the measures is testimony of the scrupulous care and skill of Flint's work. The accuracy of the results puts this catalogue among the leading ones in quality and it forms a valuable supplement to the larger *General Catalogue*. The manuscript of 24 typed sheets of text and 56 pages of tables of the catalogue is complete and awaits approval and editing for the printer.

BIOLOGY

Castle, W. E., University of California, Berkeley, California. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-36.)

The research projects initiated in the fall of 1936 under the joint auspices of the Carnegie Institution of Washington and the University of California have as yet been completed in one case only, that which involves the relation to body size of the gene mutation for albinism in the house mouse. This investigation was well advanced at the time of the last report and has since been completed and its results published. It was found that albino and colored mice, of identical parentage and genetic constitution except for the difference in color, do not differ in body size, as estimated either by body weight, body length, or tail length. The evidence is based on a back-cross population of 1252 mice reared to the age of six months, in which colored and albino individuals are about equally represented but do not differ significantly in body size.

Similar investigations are in progress to ascertain whether the mutations pink-eye₂ (of Roberts), leaden, and yellow exert any influence on growth processes so as to affect general body size. Although these experiments are still incomplete, it appears that the mutation p_2 like ordinary pink eye (p_1), which was previously investigated, exercises a retarding influence on body growth. Although these two mutations are genetically distinct and are borne in different chromosomes, they seem to have a like effect on general body growth as well as on the development of coat pigmentation. The yellow mutation, which has long been known to be lethal when homozygous and to result in adiposity when heterozygous, apparently increases body growth so that adult yellow mice are considerably larger and longer-bodied than their non-yellow litter mates.

Experiments on genetic linkage in the Norway rat have been continued in cooperation with Dr. Helen Dean King of the Wistar Institute. We have been able to obtain for study two useful new gene mutations of the rat known as "wobbly" and "anemic". A foundation stock of wobbly was kindly sent to us by its discoverer, Professor Amy L. Daniels of the University of Iowa. "Wobbly" rats have a lack of muscular coordination said to resemble the "Parkinson syndrome". The character is inherited as a simple recessive. It affects body growth unfavorably so that wobbly individuals are usually smaller than their normal litter mates at the time of weaning and subsequently. The animals of both sexes are fertile, but females make poor mothers.

The mutation "anemic" was discovered by Dr. Ralph Bogart of Cornell University, who has kindly supplied us with a foundation stock of animals carrying this defect, which is a simple recessive and lethal character. Homozygous anemics are deficient in hemoglobin and jaundiced in appearance and die usually at an age of 10-20 days.

A full program of crosses is in progress to test the linkage relations of these new genes with each other and with the other known genes of rats.

The rabbit experiments are progressing satisfactorily but less rapidly than the experiments with mice and rats because of the slower maturity of rabbits. These experiments are being conducted in cooperation with Dr. P. B. Sawin of Brown University. They are concerned chiefly with investigations of genetic linkage, the program of study, which is now well advanced, covering the linkage relations of all available known genes of the domestic rabbit. Dr. Sawin has indications of the existence of two previously unknown linkages and these are now being subjected to intensive study, the results of which it is undesirable to announce prior to full verification or disproof of the indicated linkages.

Conger, Paul, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ*. (For previous reports see Year Books Nos. 18-36.)

Studies during the year included a cooperative experimentation and examination of samples in an attempt to devise more efficient methods for separation and grading of constituent particles of diatomaceous earths for certain industrial uses.

Facilities of the laboratory were greatly improved by the installation of a fine new soapstone chemical-fume hood, to replace the former wooden one. This replacement was taken care of by the National Museum, completing their program of renovation of the laboratory undertaken a couple of years ago.

Research and field work on diatoms were carried on at the Chesapeake Biological Laboratory for six weeks during the early part of the summer of 1937, at which time also a course on diatoms, given during several previous summers, was again given, to a group of seven graduate students specializing in the fields of botany and oceanography. Additional material was obtained toward a survey of the flora of this region.

Following this a month was spent at the Trout Lake Biological Laboratory of the University of Wisconsin in the lake region of northern Wisconsin, where several hundred samples of diatom material were gathered from approximately forty different lakes and bogs. In addition collections were made at sixteen marl lakes near Waupaca in the east central part of the state. Opportunity was afforded amply to confirm the previous summer's discovery of widespread diatomaceous sediments in the northern region of potential commercial value, and some sixty of these were collected in quantity for more complete analysis and intensive study. Such study later during the year indicated a range of from 23 to 73 per cent diatom content in these materials, some of them proving extensive and of immediate practical availability. Measures have been taken to assure protection of such interests. Further investigation showed that this discovery is applicable to similar environments in other localities in widely scattered parts of the country, and should hold also in similar areas throughout the world. Equally significant and interesting from a scientific standpoint was the associated discovery of certain facts concerning the mode of formation of such valuable sediments. A fuller report on these findings is in course of preparation.

New facts and methods of presentation brought out in a paper published during the year as part of the supplement of the *Smithsonian Annual Report*, entitled "Significance of shell structure in diatoms," are as follows: (1) photograph of a section of a diatom by a new method showing the double wall structure of the shell with communicating pores; (2) photograph of a series of reproducing diatoms including two stages showing the new shells in the midst of the process of silicification, a thing not often seen, usually very obscure, and not previously figured; (3) a clear pictorial contrast of the physical properties of weight and volume between diatomaceous earth and sand, both materials of the same chemical composition, but of different structure; and (4) several new uses for the earth, or in which the diatom structure was vital.

Another paper published during the year, entitled "Exploring the lakes of northern Wisconsin," described the work being carried on up there and the differences between the lakes, and illustrated the great difference in diatom flora between hard and soft water lakes.

There was also published in the April number of the *Journal of the Washington Academy of Science* a rather full abstract of an illustrated talk given before the Washington Botanical Society, entitled "The diatom, an economic plant," emphasizing a viewpoint not heretofore considered.

The first of the above-mentioned papers from the *Smithsonian Annual Report* was copied in a somewhat modified form, as a number of the *Carnegie Institution of Washington News Service Bulletin*.

In addition to the projects of continued floristic and ecological studies of Atlantic Coast and Chesapeake Bay diatoms, an intensive study (as yet unpublished) was made of the diatoms in a series of 32 core samples collected by Dr. W. H. Twenhofel of the University of Wisconsin in representative areas of the bottom of Crystal Lake, Vilas County, Wisconsin. This is a small, round lake a little over half a mile in diameter, with very clear and very soft water. A large number of species was found, and a number of unexpected and interesting facts derived from this study. In a small lake like this with no drainage and with a rounded and uniform basin it was expected that a monotony and similarity of species would be found throughout, but such was not the case; on the contrary, marked differences were found in a number of the samples indicating quite localized areas of growth in the lake bed. Nutritive substances are very sparing in the water and a slow rate of sedimentation was suspected, confirmed by the finding of relatively thin sediments, of which fact the diatoms appeared a good indicator. It was possible through this study to make a number of suggestions as to the rate of sedimentation and the conditions that prevailed in the lake at various periods during the history of formation of these sediments.

A talk was given on April 12, before the Natural History Society of Maryland at Baltimore on "The story of diatoms in the Chesapeake Bay country," and this was repeated a couple of weeks later (April 23) at the annual meeting of the Maryland Biology Teachers' Conference.

A study was made for Dr. Chancey Juday of the University of Wisconsin on an occurrence of dense diatom growth on wall-eye pike eggs in one of

the Wisconsin state fish hatcheries, which growth was responsible for the loss of approximately 50 per cent of the eggs. The exact nature of the cause has not yet been definitely determined, but it was thought to be through a smothering of the eggs and inhibition of development, rather than through puncturing and actual mechanical injury.

The considerable increase in the number of requests for diatom information and material answered during the year indicates an appreciable growth of interest in both the scientific and the economic aspects of the subject.

Diatom investigations were carried on at the Tortugas Laboratory of the Carnegie Institution during part of the summer of 1938. Fluctuations in productivity of the region were studied through daily collections of plankton. A new species of *Amphora* was found, interesting not only in the fact that it was new but also because it was unusual and of considerable importance; and further it proved to be excellent material for certain studies on morphology and reproduction which were carried on intensively using this form. Studies on diatom reproduction were also carried on on several other species well adapted to the purpose. Some investigations of nutritive relationships and on movement in diatoms were also made. The diatom flora of the region proved unusually good for these purposes.

Dice, Lee R., University of Michigan, Ann Arbor, Michigan. *Studies of the ecology and genetics of North American mammals.* (For previous reports see Year Books Nos. 31-36.)

Most of the summer of 1937 was spent in the Capitan and Sierra Blanca Mountains of southern New Mexico in a study of the ecological distribution of the several species of *Peromyscus* which occur there. Each species has its own habitat preferences, but in this region as many as four species of *Peromyscus* may occur together in certain of the ecological associations. The species *nasutus* and *truei*, which are closely related taxonomically and which are partially fertile together in the laboratory, often live in the same situations. However, *nasutus* lives usually in lower and hotter habitats than *truei*, and no evidence was found of interbreeding in nature between the two species.

A preliminary reconnaissance of parts of the state of Chihuahua, Mexico, was made in late July 1937, in company with Forrest Shreve and T. D. Mallery, of the Desert Laboratory staff. The high grasslands and forests of the Apachian biotic province in the western part of Chihuahua are in striking contrast with the desert conditions characteristic of the Chihuahuan biotic province in the eastern part.

Most of the new breeding stocks of *Peromyscus* received by the Laboratory of Vertebrate Genetics during the year were collected in southern New Mexico, where the races *griseus*, *nasutus*, *rowleyi*, *rufinus*, *tornillo*, and *truei* were secured. W. H. Burt secured a stock of *P. maniculatus exiguus* on San Martin Island, Baja California. Mice carrying several new mutant characters were obtained from R. R. Huestis and from the Cranbrook Institute of Science. Specimens prepared during the year for studies of variation number 1755.

A study of nine stocks of the deer mouse, *Peromyscus maniculatus*, from Arizona demonstrates considerable variation in body proportions and in pelage color from place to place. No sharp separation into geographic races can be made, although most of the stocks can be assigned either to the subspecies *sonoriensis* or to *rufinus*. There is a general tendency for the pelage color on the upper surface of the mice to be correlated with the color of the surface soil of their habitats.

A detailed study of variation in the cactus mouse, *Peromyscus eremicus*, also supports the previous conclusions of Blossom and myself that the colors of desert rodents tend to be correlated with the soil colors of their habitats. On desert mountains made up of pale-colored rocks the cactus mice usually are pale in color, while on dark-colored soils the mice tend to be dark in color. An exception to this correlation is presented by Raven Butte, which is composed of dark-colored lava, but on which the mice are pale in color. This small butte is, however, directly connected with the Tinajas Altas Mountains, which are composed of pale-colored rocks. With constant interbreeding between the cactus mice living on Raven Butte and the pale-colored cactus mice living on the adjacent Tinajas Altas Mountains there has been no opportunity for the development of a dark-colored race on the butte.

A study of the social relations of the wood mouse, *Peromyscus leucopus*, in southern Michigan based on the use of artificial nest boxes has been completed by A. J. Nicholson. The mice are quite unsanitary about their nests and they desert a nest which has been occupied for a time in order to take up residence in another location. Mothers may move even their very young offspring to a new nest, perhaps because the old nest has become foul. In winter a number of these mice may live together in the same nest, perhaps for the increased warmth provided by several bodies, but in other seasons the adult mice are mostly solitary.

Methods for securing reliable estimates of small mammal abundance were given considerable attention during the summers of 1935 and 1937. Experiments were conducted with traps set in several kinds of patterns in quadrats of various sizes and also in lines of different lengths. As a result formulæ have been developed which, when the mammal population on an area is distributed relatively uniformly, should give a good indication of the population of the species studied. Quadrats of considerable size when completely trapped out give the most reliable information about populations, but valuable information may also be obtained by trapping a line of measured length.

A statistical study has been made of the theoretically possible effectiveness of adverse selection. Recessive characters respond of course much more slowly to adverse selection than do dominant, partially dominant, or sex-linked characters. Nevertheless, the proportion of defectives produced by a recessive factor will theoretically be decidedly reduced by adverse selection even when the homozygous defectives form only a very small proportion of the population. The conclusions have a bearing on proposed programs for the improvement of human heredity based on the segregation or sterilization of defectives.

Morgan, T. H., C. B. Bridges, and Jack Schultz, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-36.)

In 1935 maps of all the salivary chromosomes of *Drosophila melanogaster* were published (Bridges, *Jour. Heredity*, vol. 26, pp. 60-64). Those maps showed 3540 distinct transverse lines for the four chromosomes; but, for analyses of greater precision, more detail was found necessary. Accordingly, a thorough revision was undertaken, using specially selected permanent preparations. For the X-chromosome the revision has already been published (Bridges, *Jour. Heredity*, vol. 29, pp. 11-13) showing 1024 lines instead of the 725 of the former map, and representing all lines in better relative intensities, spacing, and characteristics. In the current year a similar revision for the right limb of chromosome 2 has been completed, with the assistance of Philip N. Bridges. This map shows 960 lines instead of the 660 of the former map. The greatly increased accuracy of the two revised maps makes it now desirable to push through without delay the revisions of the remaining maps, namely, 2L, 3L, and 3R, meanwhile deferring much of the analytical work on aberrations.

A revision of the genetic linkage maps of all four chromosomes was also carried out last year and has been published (Bridges, *Tabulae Biologicae*, vol. 14, pt. 4, pp. 343-353). This has now been supplemented by a revision of the descriptions of the mutant types of *D. melanogaster*, issued as No. 9 of the *Drosophila* Information Service Bulletins. No such revision had been made since that published in 1925 in *Bibliographia Genetica*, volume 2, pages 215-239. Careful descriptions are given of the phenotypes of the "visibles," such as eye colors, body colors, wing and bristle variants. Information is given about the special mutants such as modifiers, lethals, minutes, and the chromosomal aberrations, especially deficiencies and translocations with the break points and new sequences of chromosomal sections. The revised list includes over 3000 descriptions, of which many hundred are of mutants or aberrations not previously more than mentioned. The information given with each mutant includes: symbol, name, finder, date of origin, chromosome and locus, references to publications, description of mutant characteristics, with main and secondary changes and degree of variability, interaction effects, viability, fertility. The concluding part of each description is a summary of the relative usefulness of the mutant and its limitations.

An interesting series of five overlapping deficiencies, all of which include the vestigial locus, has been worked out by Bridges in collaboration with Viola Curry, P. T. Ives, and J. C. Li. Each of these deficiencies was first detected simply as a dominant mutation showing notchings and snippings from the edge of the wing, much like the semi-dominance shown by some strong vestigial alleles, e.g. vg-Notched of Plough and Ives. Each of the five was lethal when homozygous, and, when crossed to the others in all possible combinations, gave hybrids which died in the embryonic stages. In crosses to vestigial, which is a recessive, each of the five gave hybrids showing vestigial in an exaggerated form; hence each of the five mutants

could be either a lethal allele of the vestigial locus or else a deficiency including the vestigial locus. In wing character all were very similar, but one showed the additional characteristic of being nearly denuded of the hairs on the anterior part of the thorax and along the legs. This one was called Depillate, or *vg-Depillate*, while the others were called *vg-Beaded*, *vg-Carved*, *vg-Incised*, and *vg-Snipped*.

Definite evidence that they were due to deficiencies rather than being simply extreme alleles came when tests were carried out with two other mutants. One was "scabrous," an excellent recessive rough-eye character found by Ives and located very close to vestigial. If the locus *vg* is taken as the standard 67.0, then the locus of scabrous is 0.3 to the left, or at 66.7. The other mutation was a recessive lethal, discovered by Curry. By laborious experiments the locus of "*l(2)C*" was found by Curry to lie to

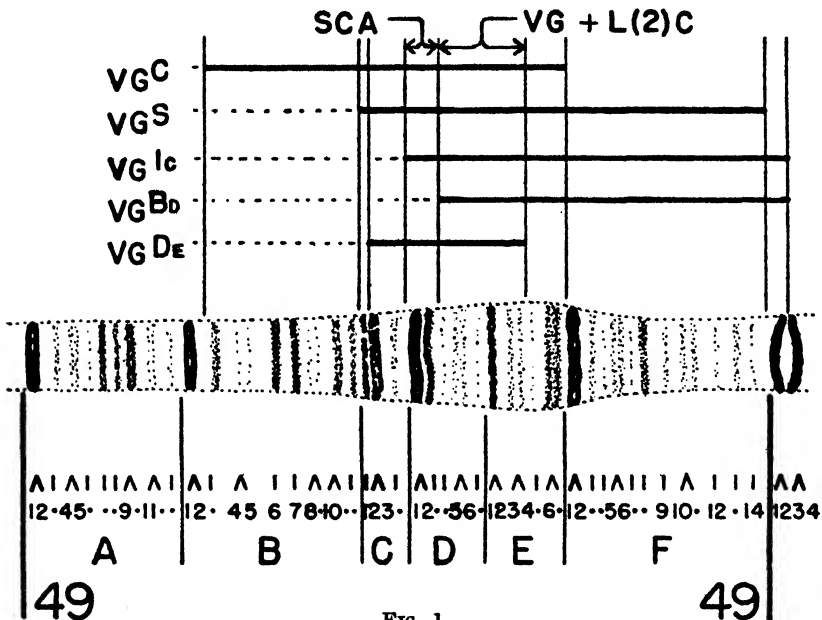


FIG. 1

the right of *vg* by 0.1 unit, that is, at 67.1. Crosses of scabrous to each of the five suspected deficiencies gave hybrids showing scabrous in an exaggerated form with *vg^c*, *vg^{Bd}*, *vg^{lc}* and *vg^s* but not with *vg^{Bd}*. Similar crosses of *l(2)C* to the suspected deficiencies gave lethal hybrids in all cases. It is considered that any dominant mutant which is lethal when homozygous and which shows pseudo-allelism to a dissimilar, non-allelomorphic but neighboring mutant is probably a deficiency. In the present case four of the dominants gave pseudo-allelism to three such non-allelic genes: *sca*, *vg*, and *l(2)C*. The other, *vg^{Bd}*, differed in that it failed to include the left-most locus, *sca*, though including *vg* and *l(2)C*. The genetic evidence is thus conclusive that each of the five is a deficiency.

This was confirmed by a study of the salivary chromosomes. Each of the five showed the loss of a fairly long section of bands. All the deficiencies

are different in the details of extent and position, but all overlap, with a zone of bands whose loss is common to all. In figure 1 is shown the normal banding of section 49, according to the revision just finished. The extent of each of the deficiencies is indicated in the figure, though there is still some uncertainty in the cases of vg^s and vg^{ps} as to the exact positions of the breaks. The shortest deficiency is vg^{ps} , extending from just to the left of 49C2 to somewhere in the faint band region of 49E. This shortest deficiency includes all three loci: *sca*, *vg* and *l(2)C*. Two others of the deficiencies have breaks within this salivary zone and serve to narrow still more the correspondence limits. Thus, vg^{ts} has its left break at the end of 49C just to the left of the two dark bands at the beginning of 49D. Since vg^{ts} also includes *sca*, *vg*, and *l(2)C*, these three loci must lie within 49D and the left half of 49E. The left break of vg^{sa} is just to the right of 49D3, and since vg^{sa} does not include *sca*, this break shows that *sca* lies within the narrow zone of 49D1 through D3, while *vg* and *l(2)C* lie between 49D3 and 49E5. Inspection of the salivary chromosomes of *l(2)C* failed to show any loss in the small region within which the locus must be situated.

It should be noted that since the wing effects of all five of the mutant types are practically identical, this character can be attributed to the loss of the vestigial locus. But the depillate character shown by one of them is not due to simple deficiency, for in that case it should have been shown by at least two others of the five, since all material lost by the *vg*-Depillate deficiency is also lost in two or more of the others. Simultaneous mutation, probably at one of the two break points, or an effect due to the new juxtaposition, must be assumed.

Study of the salivary chromosomes of *vg*-Snipped showed that it is two separate deficiencies, both presumably due to the X-raying to which Muller had subjected the parent of the vg^s mutant. The other deficiency includes the first band of 42D, which is fairly strong, and about half of the preceding subdivision, 42C, including two readily seen bands.

There was on hand another dominant mutant called *vg*-eleven which also shows wing-notching, but in addition shows smaller bristles, as in a slight "Minute." This type is lethal when homozygous. Salivary inspection failed to show a deficiency in the *vg* region. Genetic analysis then showed that vg^{11} is a double mutant type, again due to X-raying (by Sturtevant and C. Ruch). At the *vg* locus is an extreme, non-lethal, semi-dominant mutant like *vg*-Notched of Plough. The "Minute" effect is lethal when homozygous, is located not at vestigial but very close to Bristle, and gives pseudo-dominance to straw in hybrids. Hence vg^{11} is a combination of a dominant *vg* allele and a Minute which is a deficiency for straw.

Besides the Minute effect of vg^{11} , three other Minutes produced by X-rays are known which have similar location and give pseudo-dominance to straw. These are *M(S)2*, *M(S)4*, and *M(S)8*. *M(S)4* is also deficient for blot, which is mapped at 55.3, while straw is at 55.1. These four Minutes are lethal alleles of each other. None shows any detected effect in the salivary chromosomes, but since the region under suspicion is the chromocentric portion of 2R, the normal irregularities and adhesions there may be concealing the loss of bands.

A valuable correspondence has been established between the bands of the salivary map and the locus dumpy, with its numerous alleles, at 13.0 in 2L. This was through a Minute found by Curry "M(2)C" which is a deficiency for dumpy and which shows in the salivaries as the loss of the section of bands from just to the right of the faint band in 24D to half through the "shoe-buckle" set of four bands in 25A.

The well-known reciprocal translocation "Blond" has been reinvestigated. It was found that the break in the X comes between 1C3 and 1C4 of the revised map of X. To the left of this break point lie the loci: Hairy-wing, yellow, achete, scute, lethal-7e, suppressor of sable, suppressor of black, silver. To the right of the break are: stubarista, lethal-7, twisted, giant, broad, kurz, prune. The break in 2R precedes the last thin line of 60B (that is, extends to left a bit further than previously reported). To the right of this break lie speck, blistered, balloon; to the left lie 1(2)NS and 1(2)ax. The above determinations of order were made by use of the viable "Blond-Minute" derivative which is deficient for the tip of X and duplicated for the tip of 2R, and by the reciprocal "Plexate-Minute" derivative which is a duplication for the tip of X and a deficiency for the tip of 2R. It was also found that Blond is superimposed on Inversion(2R)Curly, which was presumably present when T(1;2)Bld arose. Efforts to separate the translocation from the inversion, through crossing over in the narrow space between them, were not successful. Homozygous T(1;2)Bld females survive with extreme rarity.

The preceding analyses of deficiencies and translocations are examples from extensive material bearing on the general problems of chromosome structure and on the relation between that structure and mutation on the one hand and, on the other, the breaks which lead to aberrations or to crossing-over. The evidence upon rearrangements points to the conclusion that breaks, whether spontaneous or induced, come first at random points corresponding to accumulation of strain or weakening effects. Thereafter occurs a reassemblage of the parts by the union of each fresh end with whichever other fresh end it encounters. The refusions seem to show that differences in chromosomal origin of a piece, and in polarity, i.e., whether in normal or inverted order, have no significance.

During the past year Schultz has been on leave of absence, holding an International Fellowship of the Rockefeller Foundation, and working at the Chemical Department of the Caroline Institute at Stockholm, Sweden, with Dr. Torbjörn Caspersson. The following is a brief report of their joint work.

The optical methods developed by Caspersson for the measurement of nucleic acid in the cell had already indicated a relation between the augmentation of the content of this substance in the chromosomes and the process of chromosome division. As a result of the application of these methods to the *Drosophila* material, evidence has been obtained that the nucleic acid metabolism of the chromosomes is changed in the cases of abnormal gene reproduction which are characteristic of the variegated races of *Drosophila*. These races (see the reports in Year Books Nos. 33-36) contain chromosome rearrangements involving the heterochromatic regions rich in nucleic acid; in certain favorable cases the study of the salivary gland

chromosomes had shown that the variegation is correlated with deficiencies in the salivary bands closest to the point of rearrangement, and with a darkening of the immediately adjacent remaining bands suggesting a change in their nucleic acid balance. The nucleic acid content of these bands has now been measured by a photographic method, by means of which quantities of nucleic acid of the order of magnitude of 10^{-11} mg. can be estimated. An increase of the nucleic acid content of these bands over the normal is present, greatest close to the heterochromatic regions, less farther away. A similar relation to distance from the heterochromatin holds for the variegation: the closer a band is to the point of breakage, the greater the extent of variegation for that gene.

When additional heterochromatin (an extra Y-chromosome) is present in the nucleus, the variegation is decreased in extent and the cytologically visible deficiencies are both fewer and shorter. The bands which in the XX female have more than the normal amount of nucleic acid, show in the XXY female only a slight augmentation. However, the bands which were lost in the XX female have, when present in the XXY, an increased nucleic acid content over the normal. It may be, although the evidence is not complete, that the augmentation of the nucleic acid content of a band is a stage in the loss of that band. In any case, with the change in either the distribution or the amount of heterochromatin in the nucleus, both the concentration and the total amount of nucleic acid on the affected bands are changed. The nucleic acid behavior is entirely parallel to that of the genes: the nucleic acid content of a band is dependent both on its neighbors in the chromosome (position effect) and on the general relations in the nucleus (genic balance).

Further evidence correlating changed nucleic acid metabolism with variegation comes from the study of the egg cytoplasm, in which the cell divisions responsible for variegation occur. During the oogenesis, there is a change in the absorption spectrum of the cytoplasm from one like the proteins in the oogonia, to an absorption spectrum related to that of nucleic acid in the mature egg. There is therefore in the oogenesis of *Drosophila*, a synthesis of cytoplasmic substances related to nucleic acid. That this synthesis is related to nuclear activity (although the egg nucleus is notably poor in nucleic acid) appears from the visible gradient of the concentration of such substances in the cytoplasm—highest around the nuclear membrane, and decreasing peripherally. The effect of an additional Y-chromosome has been studied and it has been found that females containing an additional Y-chromosome show an increase in the amount of these absorbing substances synthesized in oogenesis. This result has been obtained in ten series of experiments, with four different stocks of variegated *Drosophilas*. Since it is known (Noujdin) that the presence of an extra Y-chromosome in the mother decreases the extent of variegation in her XX progeny, these results show that not only the nucleic acid metabolism of the chromosomes, but that of the cytoplasm as well, influences the development of variegation. In addition there is here evident an interplay of chromosomes and cytoplasm: the Y-chromosome influences the egg cytoplasm, which in turn determines the loss of genes in the embryonic divisions, leading to variegation of the adult.

The relation of these cytoplasmic absorbing substances (probably similar to the pentose nucleotides reported by Brachet in marine eggs) to the ensuing cleavages presents a problem of related interest. The distribution of the substances in the mature egg has been studied by a special technique for the detection of very slight differences at high absorptions. It has been found that the concentration of these substances is greatest at the center of the egg, where the first and most rapid divisions occur. The correlation indicated seems, on the basis of observations of other tissues, to be a general one. Young and actively dividing tissues have a high concentration of absorbing substances.

The study of the growth of the salivary gland cells has furnished more data, of a complementary nature. In the young larva (1-2, 2-3 days old) the cytoplasm has an absorption spectrum similar to that of the substances containing the pyrimidine ring which gives nucleic acid its characteristic absorption. As the larva grows the absorption spectrum changes in a way consistent with the idea that the protein content is increasing. The absorption spectrum of the mature salivary gland shows more variability, possibly correlated with the activity of the gland at this stage. Significant is the comparison of the total absorption of the young cell with that of the nucleus alone in the mature cell. The total absorption of the mature nucleus may be as much as twice that of the whole young cell. This fact indicates a synthesis of thymonucleic acid in the salivary gland, correlated not with preparation for mitosis, but with the growth of the chromosomes and hence with gene reproduction. This is in agreement with Caspersson's finding that the stage of the mitotic cycle at which the augmentation of nucleic acid occurs is the early prophase, before the appearance of the split chromomeres.

The combined results indicate a close relation between the nucleic acid metabolism of the cell and gene activity and reproduction. There has also been found, on comparison of the band corresponding to the white gene with its normal allelomorph, a decreased amount of nucleic acid as the result of the mutation to white (see also last year's report). The extension of the method to other mutations may prove a fruitful tool for the analysis of the mutation process.

Considered in relation to the physico-chemical properties of thymonucleic acid (Hammarsten), its property of forming polymers of high molecular weight, of a long chain shape (Signer, Caspersson and Hammarsten) with an X-ray diffraction pattern with a period corresponding to that of a fully extended polypeptide chain (Astbury and Bell), the present results allow more concrete speculation concerning the nature of gene reproduction. It seems plausible to consider the process of gene reproduction as being essentially the polymerization of smaller units into a large aggregate, whose subsequent depolymerization causes division. Also relevant are the recent studies of the viruses, showing as they do the occurrence of a nucleic acid in all those adequately studied, as well as, in the case of bacteriophage, a relation between the nucleic acid portion of the molecule and its activity (i.e., its ability to reproduce itself). The possibility is suggested that the synthesis of nucleic acid is characteristic for self-reproducing protein molecules.

APPLICATION OF RESEARCH TO PROBLEMS IN CONSERVATION

Through assistance given by the Carnegie Corporation of New York, in cooperation with the Carnegie Institution of Washington, it has been possible to pursue studies bearing upon the formulation of policy and administrative procedure in the following conservation projects located in California: (1) Point Lobos; (2) Coast redwoods; (3) Old Monterey. Newton B. Drury, Research Associate in Study of Primitive Areas, who is representing the interests of the Institution in these projects, presents the following report.

Point Lobos Reserve (for previous report see Year Book No. 36). Observations have been continued along lines outlined in the Point Lobos Master Plan Report, and administrative policy has been shaped in conformity with principles developed in that report. Adoption of the recommendation by the Advisory Committee against picnic fires or smoking in the Reserve, together with arrangements for more thorough fire protection, give greater assurance against destruction of perishable values through this menace.

The State Park Commission has approved allocation of funds to acquire the off-shore rocks from the federal government, thus assuring the protection of remarkable wild-life exhibits presented by the pelicans, gulls, and cormorants on Bird Rocks, at the south end of the Reserve, and the colonies of California and Steller's sea lions on Seal Rocks near Cypress Headland. Favorable comment upon the results already apparent from the policies being pursued by the park commission at Point Lobos has been made by Dr. Joseph Grinnell, director of the Museum of Vertebrate Zoology, University of California, who was one of the scientists participating in the Master Plan Report. After a recent inspection, he wrote:

"I was intensely interested in seeing the great extent of plant succession which has developed in the brief three-year period since I first looked at the place closely. . . . All this seems to account for the changes also apparent in the bird and mammal life. . . . It is pleasing to see the natural processes going on undisturbed."

Coast redwoods. Under the direct guidance of Dr. John C. Merriam, studies of human values inherent in the redwood forests, particularly in Humboldt Redwood Park and the Bull Creek region, have been inaugurated. Following much the same pattern as the Point Lobos studies, the scientific and æsthetic features of significance in these areas are being analyzed, with a view to interpretation of the redwoods to the public and the formulation of sound policy for the protection of these forests.

In this connection, Dr. Merriam had this to say:

"Years of observation have seemed to indicate that, while much is said about grandeur and wonder and beauty, commonly the multitude passes through and is interested in the wonders, but the individuals are not able to focus attention upon particular or definite things and therefore lose much of what might otherwise be available to them from the experience. . . . A study of what should be selected and how it might be defined is a matter

for critical investigation by those who have exceptional vision and power of expression."

Appointment of a special committee to cooperate with Dr. Merriam in making these studies was authorized by the Council of the Save-the-Red-woods League at their annual meeting in San Francisco on August 29, 1938.

Monterey state historic monuments. Recent acquisition by the state of the Old Custom House on Monterey Bay, dating from the Mexican régime in California, the site where Commodore Sloat in 1846 raised the American flag and claimed the territory for the United States, has quickened interest in the historical background of this picturesque community, in which the state has a group of three historic monuments. Like St. Augustine, Florida, the city of Monterey affords opportunity for historical research and possesses relics of successive cultures that should be preserved. Studies of the Spanish, Mexican, and early American periods at Monterey have been made by Dr. V. A. Neasham of the Bancroft Library, University of California, with particular reference to over one hundred sites and structures related to Monterey's early history. A preliminary master plan for preservation of the historic meaning and landscape beauty of Monterey in harmony with its future development as a growing community has been made by Mr. Emerson Knight, landscape architect and planning adviser, and has been approved in principle by the City Planning Commission, the Harbor Committee, and the City Council of the city of Monterey.

ECOLOGY

Elton, Charles, Oxford University, Oxford, England. *Natural fluctuations in North American animal populations.*

The grant made by the Carnegie Corporation of New York and administered through the Carnegie Institution of Washington has enabled the Bureau of Animal Population in Oxford University to maintain effectively two important inquiries into natural fluctuations in North American animal populations. These inquiries have been carried out by the aid of various administrative and scientific organizations in Canada and the United States, the details being available in the published reports (see bibliography).

The Snowshoe Rabbit Enquiry is a questionnaire inquiry to field men which is mapped by objective methods at Oxford, and gives a year-to-year record of fluctuations in this rodent, which cover a huge area—practically the whole of the northern forest zone of Canada and the eastern United States. The cycle has a period of about ten years, and the very widespread action of it simultaneously in different regions suggests the possibility of a relation with climatic rhythms.

The Canadian Arctic Wild Life Enquiry is concerned with a similar fluctuation in lemmings, arctic foxes, and other arctic animals, which have, at any rate in the eastern Arctic, a marked cycle of about four years, covering also a very large area. The main part of the work at Oxford has been carried out by Mr. D. H. Chitty, who has received part of his salary from the grant, the rest of which has covered the expenses of materials, maps, photography, etc., and the coordination of other materials concerned with these cycles. The work has been supervised closely by the Director, Mr. Charles Elton, who carried on the inquiries in previous years.

The Canadian Arctic Wild Life Enquiry for 1936–1937 (mapped in 1938) will be published in the *Journal of Animal Ecology* in November 1938. The report for the previous year (see bibliography) explains the scope of its organization. The Snowshoe Rabbit Report for 1936–1937 (mapped in 1937–1938) was published in the *Canadian Field-Naturalist*.

These inquiries are providing abundant material for recording and analyzing these two important population rhythms, but it is desirable to continue them for a number of years to get a full story of their action.

The Snowshoe Rabbit Enquiry is now being linked with a five-year plan of quantitative recording of snowshoe rabbit reproductive rates at five Hudson's Bay Company posts in the North.

EMBRYOLOGY

Hertig, Arthur T., Boston Lying-in Hospital, Boston, Massachusetts. *Research in embryological pathology*. (For previous report see Year Book No. 36.)

This report concerns progress of studies on early hydatid degeneration in the human placenta originally undertaken by Dr. Arthur T. Hertig at the Boston Lying-in Hospital in 1936. These studies have been carried on during the past year by Benjamin Kropp, Ph.D., under Dr. Hertig's general direction with continued financial support of the Carnegie Corporation of New York, and collaboration of Dr. G. L. Streeter, Director of the Department of Embryology of the Carnegie Institution of Washington.

For purposes of experimental approach the work may be regarded as falling into two very general categories: (1) the relationship of angiogenesis and of blood vessel structure to early hydatid degeneration, and (2) the growth and structure of trophoblast and early trophoblastic derivatives in relation to early hydatid degeneration.

The detailed histo-pathological studies of abortuses which are the seat of hydatid degeneration have been continued. The material at hand, and constantly being added to by the pathological laboratory at the Boston Lying-in Hospital, is very extensive, and will involve much more study. Attention is being focused primarily at present on the vascular patterns of the placenta, although it is borne in mind that the material is also important for studies on epithelial structures. Certain vascular conditions involving endothelial structure, capillary form and location, as well as histological anomalies of erythroblasts, have been consistently encountered and observations along this line are being continued.

It was found desirable to verify on material available locally certain conclusions reached by Dr. Hertig in his studies on angiogenesis in the human chorion. To this end, using material of the Minot Embryological Collection in the Harvard Medical School, reconstructions of portions of the immature placenta were made, including chorion, primary and secondary villi, and their developing vascular patterns. Histological observations and reconstructions showed the presence of discontinuous capillary buds in all these structures as well as the presence of modified trophoblastic cells, angiogenic in nature, as described by Dr. Hertig.

The mineral content of the human fetal membrane in various stages is being studied by the microincineration method. A preliminary report of the results of this study on the mature amnion and chorion was delivered at the Pittsburgh meeting of the American Association of Anatomists in April 1938. A more extended statement of the results of this investigation is in preparation for publication. While it is believed that the use of this method may be fruitful, the practical difficulty of obtaining fresh material which is the seat of early hydatid degeneration may limit its usefulness to more advanced stages of hydatid degeneration.

An approach to the problem of hydatid degeneration which it is hoped will be productive deals with the factors involved in the early growth and differentiation of trophoblast, since pathological changes in hydatid degenera-

tion involve the trophoblastic derivatives so extensively. The method adopted is that of transplanting to the anterior chamber of the rat eye young rat ova at a stage when the trophoblast is highly proliferative. In the experiments performed practical difficulties were encountered in the operation and the maintenance of the graft. These difficulties have, for the most part, been overcome. While results are thus far scanty and inconclusive, the results are sufficient to show that the method should be developed and further experiments are planned.

Schultz, Adolph H., Johns Hopkins Medical School, Baltimore, Maryland.
Researches on Asiatic primates.

The man-like apes of Asia have been much less intensively studied and are less well represented in our collections than are those of Africa, yet they are of greatest importance for the full understanding of man as a primate. In order to gain new information on and more material of Asiatic primates the writer joined Mr. H. J. Coolidge, Jr., a primate taxonomist of Harvard University, and Dr. R. C. Carpenter, a psychologist of Columbia University, in an Asiatic Primate Expedition which lasted from early in January to late in September of 1937. The writer's participation was made possible through a financial contribution from the Carnegie Institution of Washington, received by special grant from the Carnegie Corporation of New York. In all his field work the writer was very ably assisted by Mr. S. L. Washburn, a graduate student in anthropology of Harvard University.

The expedition's work was carried out chiefly in northern Siam, British North Borneo, and Sumatra. Approximately 400 primates were collected, consisting of mainly the following species: orang-utan, gibbon (*Hylobates lar* and *H. cinereus*), proboscis monkey, langurs (*Pygathrix pyrrhus*, *P. cristatus*, and *P. rubicundus*), macaques (*Macaca assamensis*, *M. irus*, and *M. nemestrinus*), and slow loris (*Nycticebus borneanus* and *N. bengalensis*). In addition a series of three shrews was obtained which is of special interest to primatologists.

All these specimens were thoroughly examined in the field. They were first weighed and measured in detail, many were photographed, of some plaster casts were made, notes and sketches were gathered of most outer features, of the movability in certain joints, of the occlusion of the teeth, the condition of the mammary glands, etc. Every specimen was then skinned and autopsied. All female reproductive tracts and all embryos and fetuses were carefully preserved for later laboratory study. Internal parasites and samples of stomach contents were saved for identification and analysis; various organs were measured in the field and others preserved for study by specialists at home. Diseased and anomalous conditions were fully recorded or, in many instances, preserved, and, finally, the skeleton was prepared for shipment after certain spinal measurements had been taken on the freshly eviscerated body. Together with the hunting and observing of living apes these activities filled every available moment in the field and provided a mass of new data and of valuable material for at least several years of profitable study in the laboratory.

On his way home the writer spent eleven days at the Raffles Museum in Singapore, examining the extensive collections of gibbon, siamang, and orang-utan skulls, generously placed at his disposal by the director, Dr. F. N. Chasen. These additional data will be of greatest help in the statistical analysis of age changes, sex differences, degrees of variability, frequency of anomalies, etc., in these apes.

Since his return the writer has spent all his efforts in the preparation and study of the enormous material collected and in tabulating and analyzing the manifold and extensive field data, preparing them for later publication.

It is confidently expected that the completed work on this expedition will result in new and much-needed information on the developmental changes, the variability, the sex differences, the evolutionary adaptations, etc., in Asiatic primates, which, in turn, will help greatly to elucidate the general primate characters as well as the newly acquired peculiarities of man. So far it has been possible to complete only a few minor studies (see bibliography). In one paper it was shown that, contrary to previous claims, marked swelling of the genital region occurs in orang-utans, as it does in the African great apes, but in the former apparently only during pregnancy rather than during the menstrual cycle, as in the latter.

Another paper deals with the relative length of the various regions of the intact spinal column and demonstrates for the first time that all the higher primates differ from the lower catarrhines in possessing relatively much longer cervical and sacral regions, slightly longer thoracic region, and much shorter lumbar region. Man differs from the anthropoid apes in having the longest cervical, thoracic, and lumbar regions. In all the primates studied males differ from females in having the relatively longer cervical and the relatively shorter lumbar region.

In a third paper it is shown that in relation to the general body weight the testes of macaques are approximately twelve times heavier than those of langurs. The percentage relation averages in the former about 0.74, whereas in the latter it is only about 0.06. The corresponding approximate average is 0.08 for gibbons, 0.05 for orang-utans, 0.27 for chimpanzees, and 0.08 for man. The unequaled relative size of the testes in macaques is rendered even more remarkable by the finding that there is a greater proportion of sex-cell producing glandular tissue in the testes of macaques than in those of, for example, langurs.

Of further results can merely be mentioned so far that wild gibbons show an astoundingly high rate of old, healed fractures of chiefly the limb bones, all adults are heavily infected with *Filaria*, diseases of the joints are very common, and atrophy of one limb, cystic enlargement of ovaries, umbilical hernia, cryptorchism, etc., could be recorded in a very considerable number of cases. Anomalous formations were found in wild gibbons with surprising frequency and diversity, particularly polydactyly, brachydactyly, syndactyly, spina bifida, supernumerary nipples and teeth, forking of ribs, 8 or only 6 cervical vertebræ, fusion of atlas with occiput, etc. All this in a population of man-like apes in their natural environment gives a picture to cast doubt on the prevalence of health and normalcy in nature and on the efficacy of natural selection.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Cytogenetic and taxonomic investigations in the Crepidinæ*. (For previous reports see Year Books Nos. 25-36.)

This concluding report will review briefly the principal results of these investigations, giving references to the publications reporting these results. Several publications which are still in preparation will also be mentioned.

The original purpose of the project was thoroughly to investigate the genus *Crepis* with reference to the chromosomes of the species, the geographic distribution of the species, the cytogenetics of interspecific hybrids, and the bearing of these three lines of evidence on the taxonomy, phylogeny, and evolution of the genus.

The last published report on the chromosomes of *Crepis* is that of Babcock and Cameron¹ which treats of 108 species. At least 13 additional species have been acquired and examined and these, together with a revised list of all the species studied cytologically, will be reported in a forthcoming paper. In the genus as at present delimited (excluding *Youngia*, *Glomerata*, *Dubyæa*, and *Ætheorrhiza*) the following diploid numbers occur: 6, 8, 10, 12, 14; also among the Old World group there are several tetraploid species with $2n = 16$ ($x = 4$), two octoploid species with $2n = 40$ ($x = 5$), and possibly a decaploid species with $2n = 40$ ($x = 4?$); whereas in the native American species (except *nana* and *elegans* with $2n = 14$) only the base number 11 occurs and the following somatic numbers are found: 22, 33, 44, 55, 66, 77, 88. This unique situation in the native American species, as compared with the rest of the genus, is fully discussed in relation to geographic distribution, polyploidy, and apomixis in the forthcoming monograph by Babcock and Stebbins.²

As a supplement to the monograph of the North American species of *Crepis*, the mechanism of apomixis in these species has been studied by Stebbins and Jenkins (unpublished). In all diploid forms investigated, meiosis is normal in both P.M.C.'s and E.M.C.'s, and there is no evidence of apomixis. In the polyploids, a varying proportion of ovules in each form investigated exhibits somatic apospory followed by diploid parthenogenesis. In all the twelve forms except one (*C. occidentalis*, subsp. *pumila* apm. *hamiltonensis*) there are some ovules (usually 12-22 per cent) in which meiosis is completed and an embryo sac is formed from a megaspore with the reduced number of chromosomes.

Meiosis in the P.M.C.'s is not remarkably irregular in the apomicts, and the degree of pairing is high. Multivalents were found in all forms investigated. In a triploid *C. acuminata* the P.M.C.'s degenerate in prophase, and meiosis never begins. This degeneration is preceded by and probably caused by the degeneration of the tapetum. In *C. occidentalis* apm. *hamiltonensis* a type of restitution nucleus is formed at second metaphase and anaphase by lateral fusion of chromosome groups belonging to different spindles.

¹ Babcock and Cameron, Univ. of Calif. Publ. Agr. Sci., vol. 6, no. 11, pp. 287-324 (1934).

² Babcock and Stebbins, Carnegie Inst. Wash. Pub. No. 504, in press.

The situation in these species closely corresponds to that in *Hieracium* subg. *Pilosella*. It explains clearly the type of variation observed in nature. New forms, mostly hybrids, can be formed continually through fertilization of the eggs in occasional sexual embryo sacs. These new forms are kept constant by means of apomixis.

The geographic distribution of the Old World species of *Crepis* has been discussed in "The origin of *Crepis* and related genera."¹ The general conclusion regarding *Crepis* is that the center of origin was in southwestern Asia, and that migration from this center occurred toward the west into Europe and Africa, and toward the northeast throughout Asia and eventually into western North America. In the essay just cited there was suggested a working hypothesis concerning the phylogenetic relations between *Crepis* and three large closely related genera, *Hieracium*, *Lactuca*, and *Prenanthes*, based on the concept that 10 is the most primitive number of chromosomes in this group of genera. It should be pointed out, however, that the comparative morphology of existing species is not wholly consistent with this hypothesis, and that a broader survey of the chromosome numbers in the tribe Cichoriaceae as a whole may necessitate the adoption of a different hypothesis.

Cytogenetic studies on 11 interspecific hybrids, made by several different investigators, have been reviewed recently.² This evidence supports the evidence from comparative morphology and geographic distribution which indicates that *Crepis*, as delimited above, is a natural group of closely related species. Although several major subgeneric groups are recognized as providing a convenient basis for systematic classification, yet the species thus classified are more or less closely related, i.e., their genic complements are more or less homologous. This generalization is supported by more recent studies on groups of very closely related species³ as well as by other work on interspecific hybrids in *Crepis*.⁴

The bearing of all these investigations on the phylogeny and evolution of *Crepis* has been summarized by Babcock and Navashin⁵ and Babcock and Cameron.⁶ This evidence is invaluable in working out a natural taxonomic treatment of the genus, and it is hoped that when the general monograph is completed it will also prove of practical value for purposes of identification and classification in this genus.

Other genera of the Crepidinae to which special attention has been given during these investigations are *Youngia*;⁷ *Prenanthes*, *Dubyæa*, *Lactuca*, and *Ixeris*;⁸ *Glomeratae* (unpublished); *Ætheorrhiza* (unpublished). Furthermore, preliminary taxonomic and cytologic studies have been made in some

¹ Babcock, in *Essays in geobotany in honor of William Albert Setchell*, pp. 9-53, Univ. Calif. Press (1936).

² Babcock and Emsweller, *Univ. Calif. Publ. Agr. Sci.*, vol. 6, no. 12, pp. 325-368 (1936).

³ Jenkins, *Univ. Calif. Publ. Agr. Sci.*, vol. 6, no. 13, in press; Babcock and Cave, *Ztschr. ind. Abst. Vererb.*, vol. 75, no. 1, pp. 124-160 (1938).

⁴ Collins, Hollingshead, and Avery, *Genetics*, vol. 14, pp. 305-320 (1929); Poole, *Univ. Calif. Publ. Agr. Sci.*, vol. 6, no. 6, pp. 169-200 (1931); *ibid.*, no. 9, pp. 231-255 (1932).

⁵ Babcock and Navashin, *Bibliographia Genetica*, vol. 6, pp. 1-90, 1930.

⁶ Babcock and Cameron, *op. cit.*

⁷ Babcock and Stebbins, *Carnegie Inst. Wash. Pub. No. 484*, iii + 106 pp. (1937).

⁸ Babcock, Stebbins, and Jenkins, *Cytologia*, Fujii jubilee vol., pp. 188-210 (1937).

40 to 50 other genera mostly in other subtribes than the Crepidinæ. This survey of the whole tribe Cichoriæ has been undertaken because the subtribe Crepidinæ as heretofore constituted can hardly be considered a natural group of genera, whereas the Cichoriæ as a whole can be so considered. Hence there is reason to expect that this broader survey will throw considerable light on the phylogenetic relations of the Crepidinæ. It is hoped eventually to publish a generic revision of the Cichoriæ.

During the past year the writer has been assisted in the Crepidinæ investigations by Dr. G. L. Stebbins, Jr., taxonomist and cytogeneticist; Dr. J. A. Jenkins, cytologist and geneticist; Mr. E. Jund, technician; Mrs. J. A. Jenkins, artist.

Burks, Barbara S., Eugenics Record Office, Cold Spring Harbor, Long Island, New York. *Studies of available data in connection with research projects in the field of human heredity.* (For previous report see Year Book No. 36.)

The following report has been submitted with relation to studies undertaken at the Eugenics Record Office by Dr. Burks through support of funds granted by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The year was divided fairly evenly between the completion or continuation of projects already under way and newly initiated projects.

Studies in linkage. During the previous year, family schedules utilized from the Eugenics Record Office files had given indications of autosomal linkage between congenital tooth deficiency and hair color and possibly between myopia and eye color. To check upon these results, and to clarify points of detail, two field studies were pursued during the current year, with propositus tooth deficiency and myopia cases located through the cooperation of New York clinics.¹

The tooth deficiency field study, which made use of X-ray diagnosis and of objective appraisal of hair color and other traits, corroborated the earlier study in the detection of linkage, in the hypothesis which best accounted for the mode of transmission of tooth deficiency and of hair color, and in the estimated recombination ratio (approximately 10 per cent). The material went farther than the earlier data in permitting a formulation (through linkage relationships) of the genetic relationship of congenitally missing third molars and other congenitally missing teeth, which were formerly believed to be independently inherited. The phenomenon appears to be comparable to the irregularly selective effect of *Dichæte*, *Hairless*, *Scute*, or *Echinus* in suppressing particular bristles in *Drosophila*. These data on autosomal linkage in man were made the basis of a paper at the annual meeting of the Eugenics Research Association, and an exhibit at the annual meeting of the Genetics Society of America.

The field data on myopia, whose collection was completed toward the end of the current year, are still in the process of analysis and interpretation.

¹ Tooth deficiency cases were located through the Murry and Leonie Guggenheim Dental Clinic and the New York University Dental Clinic; myopia cases were located through Manhattan Eye, Ear, Nose and Throat Hospital.

Several other pairs of traits showed indications for linkage sufficiently promising to justify collection of further data for crucial tests of detection. Ground work has been laid for an investigation of possible linkages between somatic traits and a psychological disposition, cyclothymia. The New York State Department of Mental Hygiene has promised its cooperation in locating subjects. Dr. A. S. Wiener will collaborate by determining the blood types of subjects.

Objectivity of data. Data collected during the previous year on sets of family schedules filled out *independently* by sibling pairs, and on self-ratings compared with objective appraisals of certain physical traits, have been subjected to statistical analysis. One paper on this problem is ready for publication; another will soon be completed. The results indicate that the traits included in the available family schedules vary in the objectivity with which respondents are able to record them, and that a single trait may vary in objectivity according to the verbal definition furnished to the respondents. Certain traits have proved to be sufficiently objective to justify fully a genetic analysis of family pedigrees provided by lay respondents. A companion study utilizes the objectivity appraisals of traits for evaluating the significance of the correlations between siblings with respect to the same group of traits.

Other studies based on family schedules. In connection with major studies, it has been incidentally possible to record from the family schedules additional data contributing to a clarification of other problems. Data now await analysis upon hair color in families selected to check upon the hypothesis of transmission reached in the autosomal linkage studies, upon age changes in hair color, and upon the contribution of the grandparent generation to the abilities of the offspring generation.

Potential marital selection in a Negro group. In collaboration with Dr. Steggerda, who secured the results of a student poll at Tuskegee Institute on traits desired in an "ideal" husband or wife, analysis of data has been made together with a comparison with similar data in the literature for white students. The results give evidence that the Negro men, regardless of their own traits, tend to select according to culturally accepted norms, while the Negro women show a greater tendency toward homogamy. The Negroes of both sexes express certain preferences that tend to distinguish them from white groups. The homogamy correlation coefficients for traits of respondents and traits desired in *ideal* spouses tend to be higher than those found in other studies for the traits of *actual* spouses.

Contribution of nature and nurture to average group differences. A problem that arose out of a 1937 Milbank Fund symposium stimulated a study on intelligence hierarchies according to socio-economic group. Most of the former studies which have attempted to separate the contributions to mental development of heredity and environment have considered the problem solely with reference to *individual differences* from a group norm. For students of population it is perhaps even more important to have some method of appraising the hereditary and environmental factors contributing to differences between the *mean abilities* of identifiable *groups* (e.g., offspring of parents in professional *vs.* skilled labor occupations). A method was devised for using data from available studies of the mental abilities of

foster children and control "own" children having comparable home backgrounds. Professor Sewall Wright kindly collaborated in a "path coefficient" demonstration of the validity of the method. The accompanying figure shows the relationships upon which the demonstration and the calculations depend. Child's intelligence (IQ) can be represented as completely determined by two factors: heredity (i.e., the *child's* genetic constitution) and total environment, which may be (and undoubtedly are) more or less correlated with each other in the control group. Occupational status of father is clearly correlated with the child's total environment. The increased differences in the control data indicate that it is also correlated with the child's heredity in the controls. The reasons (involving father's intelligence) need not be represented. The conclusion was reached with respect to mean occupational group differences (of offspring) in our urban culture that nature contributes proportionally two-thirds to three-fourths, and nurture the remainder.

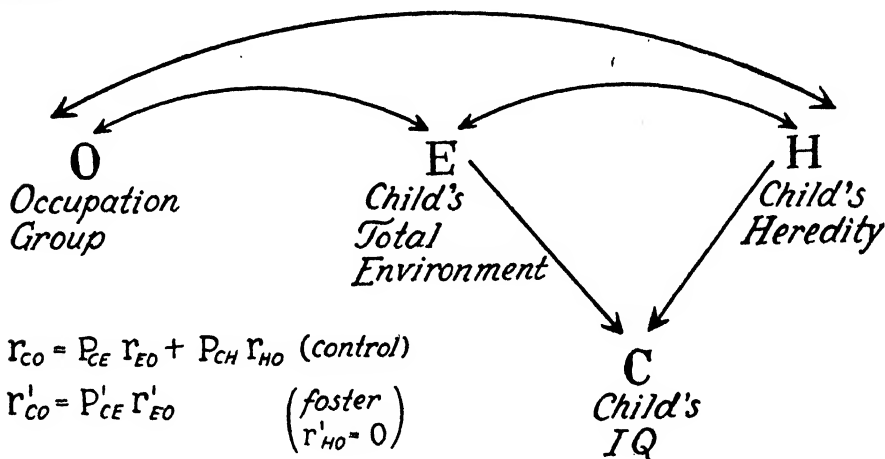


FIG. 1

Participation or cooperation in related activities. Membership and participation in related professional activities has been continued: American Psychological Association and Eugenics Research Association (papers presented at annual meetings), American Eugenics Society, Society for Research in Child Development, Advisory Research Board of Hudson State Industrial School for Girls, psychological seminar at New School of Social Research, critical reviews contributed to various professional journals.

Grateful acknowledgment is made to Dr. Streeter, Dr. Blakeslee, Dr. Davenport, Dr. Laughlin, and Dr. Bridges of the Carnegie Institution for helpful counsel, to Mrs. Jean C. Challman and Miss Anne T. Swindell, who served as field assistants, and to Mrs. Frances Carlson, office assistant.

Davenport, Charles B., Cold Spring Harbor, Long Island, New York.

Investigation on child development. (For previous reports, see Year Books Nos. 34-36.)

During the year under review the writer has continued working up the results of some fifteen years of repeated observation on the development

of individual children. This has involved the reduction of a truly formidable mass of material. At the present time the work is being continued on the growth of some dozen absolute dimensions of the cranium and some ten ratios between the dimensions; also, seven absolute measurements upon the face and the growth changes of six facial proportions; the developmental changes of six eye dimensions and four ratios in which they are involved; three absolute dimensions of the external ear (pinna) and ratios in which they are involved.

The results of the activities of the year have been incorporated in eleven publications, as listed.

On the occasion of a report to the American Society of Anthropologists emphasis was laid upon the need of a better foundation for our work upon the measurement of the living body as a basis for comparative studies of the growth of children. The errors in measurement are pointed out and consist of three types. First are observational errors including (1) errors in locating landmarks; (2) errors in measuring between two landmarks; (3) errors that arise from instrumental errors or defects; (4) the personal error. In addition to these subjective errors are objective errors due to variation in the object that is being measured; in repeated measurements of the same child one of the greatest difficulties is to secure the same posture in successive measurements. In addition there are variations connected with time of the day and the season of the year, and, finally, there are certain accidental errors connected with the reading and recording of the observations. The only way to avoid these errors is by checking, which can be accomplished by repeated measurements of the same dimension either with the same or with different technique.

A paper was prepared on the "Postnatal growth of the external nose" which has been presented for publication. The principal problems considered in this paper are: How are the size and form of the external nose determined? By what road does it attain its final proportion? How does it come to be so remarkably similar in both of identical twins? Light on this question was gained by measurement on fetuses, infants, and children between three and twenty years of age. The data discussed are both from masses, giving size-age curves, and from repeated individual measurements, constituting so-called longitudinal series. The data considered consist of five absolute dimensions and eight ratios. Nasal height increases *pari passu* with stature and attains a greater size in boys than in girls. The nasal height in proportion to body height is the same in both sexes. The individual curves of growth of nasal height show an adolescent spurt correlated with that of stature. The factor (hormone) that makes that spurt affects even the smallest of organs. The individual curves all run upward with age, but do not run parallel. Some dimensions stop growing early while others continue a vigorous growth. And in the different races the growth is different. In brothers the curves of growth are, typically, parallel but located at different levels, while in identical twins the curves are practically identical.

The growth of nasal depth follows a segment of the sigmoid curve. The nose in dwarfs and cretins is at first a shallow one. Some of our dwarfs,

independent of treatment, show a spurt of growth of nose at their (retarded) adolescence; and a treated cretin responds by deepening of the nose.

The nasal width grows rapidly before birth, corresponding to its early development in phylogeny. This dimension in Negroes continues from birth its precocious prenatal size.

The growth of the nasal salient nearly ceases temporarily at about one year, probably owing to development of the maxillæ and tooth germs. This curve has a smoother growth in girls than in boys, since in the latter the curve is depressed by the thickening of the maxilla due to development of the large permanent incisors and later by the thickening of the skin of the lips as hair follicles enlarge with the growth of a mustache. Accordingly, the curve of nasal salient in the male is very complex.

The ratios of nasal proportions often develop in complex fashion. The width-height ratio diminishes rapidly prenatally from a mean of 115 to 98, to reach a mean of 67 at maturity. Four types of growth curves between 6 and 18 can be distinguished; increasing, decreasing, U-shaped, and irregular. There is a sort of "struggle" between the vertical and horizontal dimensions during development, resulting, nevertheless, in family resemblance. Three indices show a reversal of slope immediately at or shortly after birth. Indeed, in the development of nasal proportions the bones and cartilages of the face seem quite plastic, but, nevertheless, work toward a predestined hereditary form.

In working toward the predestined end the outer nose goes along the mammalian path. Its beginnings are at the sides of the embryonic head. The cartilaginous support of the nose is laid down as a pair of tubes as in all primates; later, it breaks up into proximal and distal segments as in anthropoid apes. The elevated root of the nose is a strictly human trait; it is one of the last developed in the child.

A paper on "Bodily growth of babies during the first postnatal year," as described in the last Year Book, was published by the Institution as one of the *Contributions to Embryology*. As a by-product of this paper was published "Interpretation of certain infantile growth curves," read before the National Academy of Sciences. In this paper attention is called to the fact that the ratio of the upper and lower segments of the arm in babies is a variable one during development. Thus, for some weeks before birth the lower distal segment is growing the more rapidly. Indeed, at birth it sometimes happens that the ratio of the two segments is 1:1 in children as in some of the anthropoid apes; but whereas in anthropoid apes the ratio continues to rise, reaching 1:1.55 in the adult gibbon, in the case of the child the growth of the distal segment is much retarded after birth, while the proximal segment goes on growing so that the eventual ratio of 1:0.85 characteristic of the adult is achieved. The question raised is, Why this slowing up in the growing of the distal segment? It is suggested that there is no inherent inability of the radius to grow as fast as the humerus, both because it does so before birth and because in other primates it continues to do so. It would seem rather that a new inhibiting gene has become active in the human infant to slow down the growth of the radius. This special gene, which causes the relative slowing down of water imbibition,

cell proliferation, and collagen formation at the ends of the radius, has given man a special advantage which has aided his survival.

Certain incidental publications were prepared to meet special requests or emergencies. As Chairman of the Committee on Biographical Memoirs, the writer prepared the biographical memoir of George Davidson for the National Academy of Sciences, since the preparation of this memoir has been delayed for some forty years. As a member of the Committee on the Social Economic Goals of America of the National Education Association, he participated some years ago in the preparation of the first chapter of their just-published book on *Implications of social-economic goals for education*, entitled "Hereditary strength." Also, he prepared Appendix 31, entitled "Eugenics," in *How to live*.

In order to be in a better position to take a general view of the problem of child growth, the writer accepted the invitation of the Editorial Committee of the new *Annual Review of Physiology*, to prepare the chapter on growth, in which it is proposed to review the important literature on the subject that has appeared in the last two years.

Dobzhansky, Th., California Institute of Technology, Pasadena, California.
Genetic structure of natural populations.

In the past decades studies on the mechanics of the transmission of hereditary characters constituted the main task of genetics. Great strides forward have been accomplished in this field: the structure of the hereditary materials has been, by and large, clarified; the relationships between the hereditary particles, genes, and their physical carriers, chromosomes, understood; accurate quantitative methods for studying inheritance worked out. It is the availability of these exact methods that permits an approach to an even broader and more recondite problem, namely, that of the hereditary constitution of complexes of individuals, populations, races, and species. This problem is certainly not a new one, going back, as it does, at least to Darwin; yet only comparatively recently has it come truly within reach of modern genetics. The small flies belonging to the genus *Drosophila* furnish as favorable material for investigations in this field as they do for those along the now classical lines of the genetics of the transmission of hereditary characters. The following is a progress report covering the work on a genetic analysis of certain populations of two species, *Drosophila pseudoobscura* and *D. azteca*.

Samples of natural populations of *Drosophila* were taken in ten localities in Mexico and in eleven localities in Guatemala. A total of 194 living strains of *D. pseudoobscura* and 39 strains of *D. azteca* were brought to the laboratory, where most of them are being perpetuated. Besides these, several living strains of other species of *Drosophila*, some of them new to science, were secured. Added to the group of strains of *D. pseudoobscura* and *D. azteca* already present in the laboratory, these new strains form a part of a geographical collection of living lines in which practically every part of the distribution area of the above two species is represented.

Population samples of *D. azteca* are being worked out in collaboration with Professor D. Sokolov, of the Escuela Nacional de Ciencias Biológicas,

Mexico. *D. azteca* has five pairs of chromosomes, including a V-shaped X-chromosome, three pairs of autosomes with a subterminal or a submedian spindle fiber attachment, and one pair of dot-like microchromosomes. In the nuclei of the larval salivary glands these chromosomes are represented by six long and one very short strand; two of the long ones correspond to the X-chromosome and the short one to the microchromosomes. Reference "maps" showing the disk patterns in all the salivary gland chromosomes of an arbitrarily chosen standard strain were prepared. Any deviation from this normal or standard gene arrangement observed in other strains may now be described in terms of the standard maps.

All the strains of *D. azteca* were outcrossed to the standard strain, and the chromosomes were studied in the salivary glands of the hybrid larvæ. If the hybrids have seven normally paired chromosomal strands, it follows that the strain tested has the same gene arrangement in all the chromosomes as the standard one. Any difference in the gene arrangement results in formation of characteristically abnormal pairing configurations, from the inspection of which the precise nature of the difference may be deduced. Indeed, strains of *D. azteca* prove to be frequently different from each other in the gene arrangement. All the variations thus far detected are due to inversions of blocks of genes within a chromosome.

A total of three gene arrangements has been established in the long, and two in the short limb of the X-chromosome, six in A-chromosome, and four in B-chromosome. Several gene arrangements may be found in the population inhabiting the same locality, and even in the offspring of a single female or male caught in nature. Nevertheless, in no locality is the entire variety of the gene arrangements present; on the contrary, the species is geographically differentiated, so that strains coming from geographically remote regions are more likely to have the chromosomes differently constructed than strains from the same locality. Thus, all the strains from Guatemala and south central Mexico have a gene arrangement in the X-chromosome that apparently does not occur in California strains; in north central Mexico (Durango) both the southern and the California arrangements occur in the same population. It is justifiable to speak of the formation of chromosomal races in *D. azteca*. ✕

Some of the gene arrangements found in A- and B-chromosomes proved to be related to each other as overlapping inversions. As shown by Sturtevant and Dobzhansky, overlapping inversions permit the construction of phylogenetic schemes indicating the manner in which the gene arrangements in question may have descended from each other. Such phylogenetic schemes have been prepared for A- and B-chromosomes of *D. azteca*. Among the gene arrangements known in A-chromosome those forming one end of the phylogenetic chain occur only in Guatemala and southern Mexico, and those forming the other end only in California. The arrangements occupying the middle portion of the chain occur in north central Mexico (Durango). On the basis of facts such as these certain inferences regarding the history of the species and of its distribution and migration in space become possible.

The "sex ratio" condition previously known in *D. obscura*, *D. pseudoobscura*, and certain other species has been found also in wild populations

of *D. azteca*. Males carrying the sex ratio factor in their X-chromosome produce mainly daughters, and few or no sons. The sex ratio condition in *D. azteca* is associated with a triple inversion in the long arm of the X-chromosome. The three inversions are independent, that is, separated from each other by segments of the chromosome that have the same gene arrangement in chromosomes carrying and not carrying sex ratio. It is not easy to see what mechanism keeps these three inversions in the same chromosome and does not permit them to be separated by crossing-over with normal chromosomes.

An analysis of the population samples of *D. pseudoobscura* from Mexico and Guatemala is now in progress, so that only very preliminary results can be reported. This analysis is being carried on along two main lines: a cytological study of the variations in the gene arrangement, and detection of the concealed genic variability in the third chromosome. The gene arrangement is highly variable in Mexican and Guatemalan populations. Altogether nine arrangements, one of them not known previously, have been found. The relative frequencies of the different arrangements are unequal in populations from different localities. In this respect populations from central and southeastern Mexico form one group; those from west central Mexico form another; those from Guatemala the third. Even within these regions no uniformity prevails; populations inhabiting a given locality may vary rather independently from those living in neighboring localities. For example, 14 out of the 90 third chromosomes analyzed from Pachuca (Hidalgo, Mexico) proved to have the "Olympic" gene arrangement. The Olympic arrangement is known also from the Olympic Peninsula, Washington, and from the vicinity of Patzcuaro (Michoacan, Mexico), but it has not been found in localities relatively much closer to Pachuca. This suggests that the frequency of a given chromosome structure, or a given gene, in a population may be subject to large fluctuations due to isolation and to restriction of the effective size of the breeding population. Such fluctuations were postulated on theoretical grounds several years ago by Sewall Wright.

It has been shown before that in natural populations of *D. pseudoobscura* inhabiting certain mountain ranges in California about 12 per cent of the third chromosomes carry recessive lethals, 3 per cent semi-lethals, and about 40 per cent genes causing minor decreases in the viability. Preliminary data for Mexican and Guatemalan populations seem to indicate an even greater infestation of the germ-plasm by deleterious recessives. Among the 120 wild third chromosomes analyzed, 25 chromosomes, or 20.8 per cent, carry lethals, and at least 9 chromosomes, or 7.5 per cent, definite semi-lethals. The frequency of the modifiers of the viability that are not classed as semi-lethals is not yet determined, but it is certain to be very high.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-36.)

Investigations. Professor J. Bjerknes and Dr. E. Palmén finished in the fall of 1937 their aerological investigation of Case 4, February 15-17, 1935 (mentioned in previous reports; published in *Geofysiske Publikasjoner*, Oslo, 1937). That investigation, together with three earlier ones in the same series, will now form the empirical basis for the textbook treatment of the dynamics of cyclones, with which J. Bjerknes is at present occupied.

The fundamental problem of the cause and origin of pressure variations, which must be tackled in any thorough treatment of the dynamics of the atmosphere, has found a satisfactory solution through a simple mathematical theory developed in connection with the aerological investigations. J. Bjerknes presented that theory at the annual meeting of the Deutsche Meteorologische Gesellschaft in Frankfurt in October 1937 and published it in the *Meteorologische Zeitschrift* in December 1937. The theory is "quasi-static" and states that the pressure variation at a fixed point of an arbitrary level h is due to the combined action of the following three processes: (1) *Vertical air motion effect.* Upward motion at the level h increases (and downward motion decreases) the weight of the air column above h , and the pressure at the fixed point varies accordingly. (2) *Horizontal advection effect.* In the general case, when horizontal density gradients exist, horizontal advection either increases or decreases the weight of the air column above h and thereby influences the pressure at h in the same sense. (3) *Horizontal divergence and convergence effect.* If horizontal divergence prevails from h upward, the weight of the fixed air column above h decreases, and the pressure at its base decreases in consequence. If convergence prevails, the opposite result takes place.

The vertical air motion effect vanishes at the earth's surface, wherever this is strictly horizontal. In the free atmosphere, however, the vertical air motion is often the cause of important pressure variations. In fact, the upper "lows" initially form by the descending motion over polar air which spreads along the ground behind the polar front waves. Likewise, at the initial formation of an upper "high" the ascent of tropical air plays an important part.

The horizontal advection effect is represented in typical form at the frontal surfaces and produces, when acting alone, a fall of pressure in front of warm fronts and a rise of pressure behind cold fronts. The tropospheric and stratospheric contributions to the advection effect are systematically of opposite sign, usually with the tropospheric part predominating.

The horizontal divergence and convergence effect explains, among other things, the propagation and partly also the intensification of the upper perturbations. Provided that the air of the general upper current goes faster than the perturbation (a condition which is usually fulfilled), diver-

gence and fall of pressure is developed ahead of the upper "low" and convergence and rise of pressure is developed behind it.

Both the advection and the divergence (convergence) effects bring in the influence of all upper layers, even the very light uppermost ones, on the variations of barometric pressure at the level h . It is, however, evident from the mathematical expressions of these effects that the influence of a layer of unit thickness becomes smaller the higher up it is situated. The theories based on a preponderating influence of stratospheric processes, which have played a great part in meteorological discussions of recent years, therefore must be refuted.

Redactional work. The manuscript of the new edition of part I, "Statics," may be considered as practically completed (170 typewritten pages and a considerable number of illustrations). This will in print be a book of about the same size as the old edition, but with a much richer content. Large parts of the old book could be abbreviated, since the innovations it introduced have been universally accepted (units, proper variables, etc.). Special sections have been devoted to radiation and to atmospheric thermodynamics, which were not treated in the old edition. The theoretical parts of the volume have been written by Dr. Godske, the section on aerological methods by Godske and J. Bjerknes.

The manuscript of the new edition of part II, "Kinematics," may also be considered as almost completed (150 typewritten pages plus numerous illustrations). This volume will consequently but slightly exceed the size of the old edition, but the content is more exhaustive than before for reasons similar to those given above. An addition of considerable practical importance deals with Dr. Petterssen's "kinematical prognosis," and with the problems of frontogenesis and of frontolysis. The entire volume has been written by Dr. Godske.

The greatest progress of the year consists in the preliminary redaction of the theoretical chapters of part III, "Dynamics." Numerous attempts at giving form to these chapters have been made during the last twenty to thirty years. The difficulties met therein are chiefly responsible for the delay in the finishing of our work. At first there were no definite goals to aim at, and we tried to develop the theoretical tools for dealing with problems of a rather indeterminate character. But, as time went on, the empirical discoveries made the main problems take more precise forms. Then the question arose to what extent these problems could be mastered mathematically. We have now reached a point where we know fairly well to what extent this is possible with our present empirical knowledge and with our present mathematical resources.

It has now proved possible to write a first, relatively complete, draft of the theoretical part of the volume. The work has been mainly in Dr. Godske's hands. He has written a manuscript of about 250 pages divided into the following five chapters: (1) the hydrodynamical equations of meteorology (34 pages); (2) discussion of the hydrodynamical equations by use of line integrals (31 pages); (3) special motions, steady and others (51 pages); (4) stability and instability; turbulence (61 pages); (5) equations of perturbations and the wave theory of cyclone formation (69 pages).

Although the manuscript is a preliminary one, there is no reason to expect that much rewriting will be necessary.

The remaining part of the volume will be of empirical and practical nature in closest possible contact with the theoretical part. It will finally present the methods of weather map analysis and of weather forecasting. The work will be mainly in the hands of Dr. Godske and Professor J. Bjerknes, with the advice of other investigators, as Dr. Bergeron and Professor C. G. Rossby (of the Massachusetts Institute of Technology, Cambridge). It may be hoped that the preliminary manuscript of the remaining chapters of part III will be ready in the course of the coming year. After that only the last finish remains to be given to the entire volume as well as to the entire work.

NUTRITION

Ritzman, E. G., University of New Hampshire, Durham, New Hampshire.
Cooperative researches on the nutritional physiology of the adult ruminant.

With the retirement of Dr. F. G. Benedict during this year the results of our cooperative researches carried on at Durham on cattle have been compiled and made public (*The nutritional physiology of the adult ruminant*).

The studies in animal nutrition carried on cooperatively with the Nutrition Laboratory of the Carnegie Institution of Washington have been primarily of a fundamental nature. The attempt has been to build a more solid foundation of physiological fact for the still relatively uncertain structure which is now available as guide in the practical requirements of feeding livestock economically.

During the past nineteen years of our cooperation this laboratory has carried out many metabolism experiments with many animals of different species of farm live stock. These represent 13 experiments with horses, including a thoroughbred stallion with a notable turf record, a blue-ribbon Percheron stallion weighing over a ton, a Percheron mare, a standardbred or trotting gelding, a range pony, and a very small Shetland pony weighing about 300 pounds; about 300 experiments with eighteen beef steers; 4 experiments with bulls; over 50 experiments with twelve dairy cows; over 200 experiments with about one hundred sheep; about 30 experiments with thirteen goats; and 20 experiments with pigs ranging from a boar weighing 600 pounds down to suckling pigs weighing less than 10 pounds.

The primary objective has of course always been to determine basic physiological principles to serve as a solid foundation on which problems of immediate practical concern can eventually be solved more intelligently. These problems relate not only to the best economic interests in feeding of livestock, but also to nutrition as it affects health and efficiency, so that a sound physiological background of the animal organism as a transformer of energy has a potential significance in its application beyond the particular species on which it has been determined.

These researches have brought out many new facts of interest relating both to technique of conducting such work and also to metabolism and nutrition, many of which have previously been made public in the form of bulletins, contributions to scientific journals, and monographs.

These studies have in a large measure been devoted to a determination of the needs of the animal organism for its own maintenance (i.e., basal metabolism) in support of life under various conditions of season and climate, and particularly to the comparative efficiency of the different species of farm livestock as energy-consuming organisms. Thus it has been found that the horse has the highest basal metabolism per unit of size of any animal so far measured. It is nearly twice that of the rat, the goat, and even of man, a fact which may explain this species' extraordinary capacity for speed and endurance, but likewise indicates a higher need for maintenance.

The outstanding feature of these investigations is the discovery that the influence of certain factors affecting the basal metabolism of adult dairy

cattle has heretofore been entirely unsuspected. These factors relate primarily to (1) the remarkable lability of the basal metabolism of adult cows and the tendency of the basal metabolism to vary in this genetically highly specialized animal, and (2) the extraordinary effect of lactation on increase in basal metabolism. The concept held for many years that the rate of metabolism, or basal heat production, is conditioned solely by the rate of heat loss to the environment is thus rendered untenable. The results from comparative types (such as highly developed beef and dairy stock) suggest the far more logical theory that basal heat production varies with functional adaptations and their respective requirements and that these are determined by internal factors (hormone stimulus).

While these studies have heretofore been carried out entirely on adult individuals, a study of the metabolism during growth, on which relatively but few experimental data exist, has been begun during this year. This has been carried out with eight Holstein heifer calves from purebred ancestry whose annual milk production records are known.

It is planned to study these heifers periodically from the age of about eight months (when the experiments were begun) through at least one and possibly two lactations. Thus three series consisting of sixteen complete energy and nitrogen balances and twenty basal metabolism measurements were carried on during this past year (July 1, 1937 to July 1, 1938).

Besides the more immediately practical ends of determining the energy and protein requirements during growth, this study presents critical physiological potentialities. Thus this first year's results have already demonstrated an extraordinarily high tissue stimulus during growth, which is nearly double that of the adult dry and farrow cow and compares more nearly with that of the adult when lactating. The interrelationship between the tendency to early maturity, a high lactating potential, and a differential in degree of tissue stimulus (i.e., basal metabolism) presents many attractive problems for the physiologist, which may help to build a foundation or basis for predicting the eventual producing ability in young dairy stock, which has so urgently been sought by dairymen.

In a series of experiments carried out monthly throughout the year on an adult Chester White pig a considerable variation in basal heat production was obtained although the food and the experimental temperature were maintained constant throughout the series. The highest basal metabolism (19.2, 19.3, 19.0 calories per kilogram body weight) occurred during March, April, and May, and the lowest (15.5, 14.9, and 14.3 calories per kilogram body weight) was obtained respectively during the months of June, July, and August. While the extreme difference (about 35 per cent) reflects a tendency to vary somewhat similar to that already reported for adult dairy cows, the high values appear earlier in spring and the lowest basal heat production of the pig occurs during the months of highest basal heat production by the cows. At present this can be explained only by difference in life habits of the two species, particularly during the hot season from June to August, when the cows were kept on pasture exposed to sunlight and other variable weather conditions during the entire day (except of course

during the actual period of the experiment), while the pig was kept in a shaded pen.

These results obtained on the pig tend, however, to support the general conclusions suggested by the results with adult dairy cows relative to a lability in the basal metabolism and its causes.

A series of experiments at different environmental temperatures ranging from 11.0 to 24.1° C. showed no effect of temperature changes on the basal metabolism within these limits, suggesting that the improved breeds of this species have a sufficient insulation of fat to protect them against a drop in temperature at least down to the neighborhood of the freezing point.

Subsequent to this series of seasonal range of experiment, the pig was bred and its basal metabolism was measured monthly until one week after parturition, that is, into the early stage of lactation. At 41 days of pregnancy the basal metabolism was only 6 per cent above the previous level, at 75 days it was 43 per cent above, and at 103 days (11 days before farrowing) it was 53 per cent above original basal level. If we correct this latter value (which would be the only one materially affected) for the seasonal influence, it becomes 45 instead of 53 per cent. The influence of pregnancy is then along the order previously reported for sheep (New Hampshire Exper. Sta. Tech. Bull. 45, and reprint from *Wissensch. Arch. f. Landwirtsch.*, Abt. B, *Arch. f. Tierernährung u. Tierzucht*, vol. 5, no. 1, pp. 64-67, 1931). The significant feature is the extraordinary influence of lactation on the basal metabolism, which at this early stage is 62 per cent above the original basal level. This again, as reported for cows (Carnegie Inst. Wash. Pub. No. 494), indicates the tremendous internal stimulus to which the tissue cells of the body are subjected in the process of milk formation.

The difficulties met in locating some firm capable and willing to build a suitable mask has delayed the proposed project of studying the effect of work on the energy expenditure of the horse. This has now been overcome and the necessary preparations will be completed so that preliminary experiments may be carried out within a few months.

A series of experiments have also been begun to study the effect of ingestion of pure sugars (glucose) on the respiratory quotient of the ruminant. Three experiments with glucose and two controls have so far been carried out on goats. These are merely a contribution to the larger program carried on by Dr. T. M. Carpenter in a study of the effect of sugar on metabolism which has been under way for several years.

Sherman, H. C., Columbia University, New York, New York. *Influence of nutrition upon the chemical composition of the normal body.* (For previous reports see Year Books Nos. 32-36.)

Last year we reported the completion of the experiments upon the relation of food to length of life, made possible by grants from the Carnegie Corporation of New York through the Carnegie Institution of Washington. The data of the last of these experiments have now been prepared for technical publication in the *Journal of Nutrition*. The two outstanding results of the five years' research thus completed are (1) the finding that scientific adjustment of the quantitative proportions of a simple mixture of natural

foods yielded as favorable an outcome in nutritional well-being and length of life as did more diversified diets, and (2) that calcium, vitamin A, and what we previously called vitamin G and now call riboflavin were all significant factors in our previously recorded nutritional improvement of an already adequate dietary.

One of the by-products of that research was the finding that well-diversified dietaries no poorer in calcium than are sometimes met in ordinary human experience may, when long continued, result in a decline of well-being apparently due to a lowered calcium content of the body. More directly in line with the constructive aim of our research as a whole is the converse question thus suggested: whether increasing the level of the nutritional intake of calcium from one of slightly above minimal adequacy to the more liberal intake which induces more nearly optimal results in our full-life and successive-generation feeding experiments would be found measurably to increase the calcium content of the normal body. With the approval of the President of the Institution the small balance remaining from the grant in aid of the previous work has been devoted to this new research.

Two main series of experiments were begun, using as respective starting points or basal dietaries the Diets A and B which have been described in our reports upon the preceding research. (Tentatively, and to a limited extent, these are being supplemented by experiments employing diets of higher protein content.)

The general principle of constancy of chemical composition among the normal members of a species, a hypothesis which has been so widely influential, and for so long a time, as to have been called "Liebig's law of the minimum," had tended to bias biochemical thinking against the idea that nutrition could significantly influence an already normal percentage of any chemical constituent of the essential tissues of the body. But the present-day dynamic view of physico-chemical phenomena which suggests that the introduction of different amounts and proportions of such active factors as certain salts and vitamins into the system must be expected to shift some of its concentration levels and equilibrium points, and the definite objective findings of nutritional improvement of the already normal in our full-life and successive-generation feeding experiments, now together reopen the fundamental questions, how specific is a species in its quantitative chemical composition? and to what extent or how significantly may the nutritional intake influence the body composition within a normal range?

Here, as in our investigation of the influence of food upon general fitness and upon length of life, the experiments yield clearer evidence when continued into a second generation. In our first series of such experiments, parallel families or breeding lots were made up at the end of infancy (rats at four weeks or one month of age) and thenceforward received, respectively: (1) the original or basal Diet 16, also designated as Diet A in some of our publications, which is known to be adequate in that families are thriving on it in the forty-fourth generation, but which in its calcium content of 0.20 per cent of the dry matter is probably but slightly above the level of minimal adequacy for permanently satisfactory results generation after generation; (2) Diet 168, made by adding to Diet 16 enough calcium carbonate to raise the calcium content to 0.64 per cent; (3) Diet 169, made by

the further addition of calcium salts, in this case carbonate and phosphate, to bring the calcium content to 0.80 per cent with the same ratio of calcium to phosphorus as in Diet 168.

Offspring of the families on these three diets have been analyzed for calcium at the ages of one, two, three, six, and twelve months of age, i.e., at fixed points ranging from the end of infancy to full adult status in the rat. These results show: First, the normal process of calcification in the growing body was greatly expedited by the more liberal levels of calcium content of the family food supply. Throughout a long period of rapid growth the young from the families having liberal-calcium food contained from one-fourth to one-half more body calcium (reckoned either in amount or in percentage) than did their cousins from families which were receiving a dietary of only slightly above a minimal adequate calcium content. Secondly, it was found that the percentage of body calcium as "plateaued" in the adult was permanently higher for those on the dietaries of liberal calcium content. In other words those which received a dietary of slightly over minimal adequate calcium level never fully caught up, in the percentage of calcium in their bodies, with those whose dietaries were three- or fourfold richer in calcium.

These findings show a larger influence of nutrition upon at least one aspect of the composition of the normal body than could have been anticipated from the long-accepted generalization which we now see to have been too dogmatic. As a basis for the more discriminating generalization now needed, it is clearly desirable to develop this research in at least two directions: the further study of calcium from different dietary starting points, as mentioned above; and experiments with graded levels of intake of other essentials, to measure their effects upon the body-concentration levels of these substances themselves and of others with which they may be interrelated in the nutritional process.

The significance of this may perhaps be more fully apparent when viewed as a substantial revision not only of Liebig's generalization but also of its physiological corollary formulated by Claude Bernard in his well-known saying that it is the *fixité* of the internal environment which enables an organism to cope with a new or changeable external environment. Useful as this idea has been, it now stands in need of revision. The postulated "fixité" of the internal environment is only an approximation. Its flexibility and the influence thus exercised by nutritional differences within the normal range can now be seen as measurably influencing the quality and duration of life. We hope now to explore the possibilities of obtaining further light in this field through the direct approach of quantitative chemical investigation of the tissues of animals, all normal, but differently fed. This chemical information is to be sought in part by the methods of chemical analysis as hitherto understood and in part by recently developed quantitative feeding methods.

The validity of these new methods of research and the far-reaching significance of such differences as can be nutritionally induced within the normal body are encouragingly indicated by the preliminary results already obtained.

The efficient services and constructive suggestions of those who have collaborated in this investigation, whether as research assistants or as volunteers, are gratefully acknowledged.

Vickery, H. B., New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-36.)

The comparative studies of the new salt mixture 351, reported in 1937 (Year Book No. 36), with the old Osborne and Mendel salts have been continued. Experiments on reproduction and on longtime growth have indicated that the new mixture is well adapted for rapidly growing albino rats.

In the earlier work, it was shown that, if the food contained either 2 g. of salt mixture 351 or 4 g. of Osborne and Mendel salts, growth of the male albino rat at a rate in excess of 5.0 g. a day for the period of growth from 60 to 200 g. body weight could be expected. With foods that contained either salt mixture in the amounts indicated, the animals would, if permitted free access to food, consume on the average about 50 mg. of calcium and 34 mg. of phosphorus per day, and the ash of the dry fat-free femurs would be approximately 58 to 60 per cent. The more recent studies have been directed toward a determination of the exact requirement for calcium and for phosphorus for different periods of growth. To aid in this study, a salt mixture, no. 371, similar in composition to 351 salts except that it does not contain calcium and phosphorus, has been used. It is thus possible to vary the amounts of calcium and phosphorus to be added to the food without making changes in the proportions of the other inorganic constituents and also to compare results obtained with those observed when the standard salt mixture, 351, is used as the source of inorganic constituents of the food. In the work of this laboratory, this new salt mixture has replaced the calcium- and phosphorus-free one (XXX) used by Osborne and Mendel in 1926, and in subsequent years in the investigations that were conducted in collaboration with Dr. E. A. Park. The composition of salt mixture 371 is as follows:

MgCO ₃	58.0	grams
MgSO ₄	38.0	
NaCl	162.0	
KCl	260.0	
K ₂ CO ₃	197.0	
Citric acid	209.0	
Ferric citrate	70.0	
KI	0.75	
MnSO ₄	0.85	
NaF	2.3	
Al ₂ (SO ₄) ₃ ·K ₂ SO ₄	0.4	
CuSO ₄	2.2	

The quantities refer to "reagent" or "c.p." salts.

A satisfactory technique for feeding measured amounts of calcium and phosphorus each day has been developed. The general method of experimentation has been described before (Year Book No. 31). Male albino

rats are fed the measured amounts of calcium and phosphorus salts from weaning (21 days of age and 50 to 55 g. body weight) until growth is terminated at 200 g. body weight. As in work previously reported, the ash of the dry fat-free femurs is used as a measure of the degree of calcification. The early results indicate that it may be definitely advantageous to the development of the skeleton of the rat to vary the proportions of calcium and of phosphorus with changes in body weight. A final report on these experiments will be given in a journal paper later in the year.

The effect of the intraperitoneal injection of thymus extract on the growth and development of the albino rats of this colony has been studied at intervals, as material became available, since 1934. This work has been done in collaboration with Dr. Leonard G. Rowntree of the Philadelphia Institute for Medical Research. Dr. Rowntree has generously supplied the thymus extract that has been used throughout the investigation. When this work was undertaken at the suggestion of the late Professor Mendel it was hoped that it would be possible to duplicate with the animals of this colony the results obtained by Dr. Rowntree and his colleagues. They had demonstrated that the offspring of thymus-injected rats showed marked acceleration in early growth and in the development of certain organs. It was planned to study the effect of this rapid development on the skeletal system.

The injection of the thymus extract has been continued through many generations of animals in several series of experiments. In some of the early trials there seemed to be a slight increase in the growth rate of the offspring of thymus-injected animals in comparison with the rate of growth of untreated animals. In recent months, however, that has not been true, and in many cases growth has been markedly subnormal. There has never been any indication of precocity such as early eruption of the teeth, appearance of hair, and opening of the eyes, as has been reported from the Philadelphia laboratory. Inasmuch as the rate of growth of the animals of this colony is so much higher than in that at the Philadelphia Institute for Medical Research, it seemed desirable to try the effect of another stock food, to see if, with a slower "normal" growth, there might be increased rate of development with the use of the thymus extract. Consequently, animals have been fed the stock ration supplied by Dr. Rowntree, and have been given the usual intraperitoneal injections of thymus extract. The young of these thymus-injected parents are smaller at all ages than those from injected parents fed the regular stock ration of this colony. There has been no evidence of precocity.

In an attempt to determine a cause for the failure of the animals of this colony to develop more rapidly when thymus extract was administered, a comparison has been made of the weights of the thymus glands from the offspring of thymus-injected parents with those from animals of the regular stock. Several years ago, Moment, working with animals from this colony, made extensive comparisons of the organs of rapidly and of slowly grown rats. One of the most striking observations that he made was that the thymus gland of the rapidly grown rats was much larger than that of the slowly grown animals. As he states in his summary: "The behavior of the thymus is unlike that of any other organ. Its size in quick growth

rats is, in every group, much greater than in slow growth ones, and may be 300 per cent greater. But the time at which the size is greatest and that at which it gets smaller is the same in the two series, even though the body sizes are very different." With the limited number of animals that have been available since this phase of the work was started (only 40 from thymus-treated parents), there has been observed a marked difference in the weights of the thymus glands at different ages. The thymus glands from untreated stock animals are significantly larger than those from rats born of thymus-injected parents. The differences are not as great as those observed by Moment in his comparison of quick-growth and slow-growth rats.

With the aid of Dr. G. W. Pucher and of other members of the Experiment Station staff attached to this laboratory, we have completed a study of the behavior of the stalks of the tobacco plant when these were subjected to culture in water, both in light and in darkness, under conditions similar to those we employed in earlier investigations of tobacco leaves. The results have been published during the past year in a bulletin from this station. The stalks, denuded of all leaf tissue, were cultured for 332 hours, analyses being made at convenient intervals so that the results could be plotted on curves which showed the increase or decrease of the analytically determinable components. Towards the end of the experimental period, shoots appeared at the upper nodes of many of the stalks, those in darkness developing into elongated colorless stalk-like branches with rudimentary leaves, those in light developing into small sessile green leaves. This behavior was taken as evidence that vegetative processes could continue in the material and that the experiment revealed changes in tissue that was still alive, abnormal as the conditions of culture may have been.

The water content of the stalks at first increased slightly and then slowly diminished; even at the end of 330 hours only 10 per cent of the initial water had disappeared. The organic solids diminished appreciably in darkness but changed very little in light. The loss in darkness was doubtless due to respiration; the maintenance in light indicates that photosynthesis occurred in the green cortex tissue in sufficient amount approximately to compensate for respiration losses.

The amide nitrogen and the soluble amino nitrogen both increased and there was a slow but significant increase in ammonia nitrogen. Evidence of the synthesis of glutamine in light was secured, and it is probable that the general metabolism of both glutamine and asparagine did not differ qualitatively from that characteristic of leaves under similar conditions. Quantitatively, however, the changes were small.

The organic acids increased slightly early in the culture period and thereafter diminished. Oxalic acid did not change; citric acid increased significantly in the dark, exactly as it does in leaves, but diminished slightly in light. Malic acid increased both in light and in darkness though more slowly in the latter case. The increase in darkness is in sharp contrast to the behavior of malic acid in leaves under similar conditions.

By far the most important changes, from the quantitative point of view, were those of the carbohydrates. Whereas in leaves the carbohydrates increase rapidly and very materially in light but decrease rapidly in dark-

ness, in the stalk the soluble carbohydrates diminished under both conditions, although less rapidly in light. The initial soluble carbohydrate content was much higher than is usually found in leaves of the same variety of tobacco plant; the final value was comparable to that observed in normal leaves. The changes can be interpreted to represent the effects of respiration, the slower rate of carbohydrate loss in light being due to the compensatory effect of photosynthesis.

The loss of organic solids due to respiration during culture of tobacco stalks in darkness could be accounted for fairly accurately in terms of the loss of soluble carbohydrates. With leaves, on the other hand, the respiration loss was considerably greater than the loss of carbohydrates and it was apparent that substances other than carbohydrate were drawn upon.

Our results with tobacco leaves and stalks have been of the greatest assistance in the interpretation of data secured during the culture of rhubarb leaves. Preliminary experiments with this material were reported last year. The object of our study was to see if rhubarb leaves differ in any fundamental manner from tobacco leaves with respect to the metabolism of nitrogen, of organic acids, and of carbohydrates. Differences were to be anticipated inasmuch as the rhubarb plant is one of the group classified by Ruhland and Wetzel as acid plants. These species are supposed to differ from the more nearly neutral species with respect to the metabolism of ammonia. In a paper published recently, we have shown that rhubarb leaves when cultured in water in darkness become strikingly enriched in glutamine, but the apparent increase in asparagine is small. A careful study of the material separated by direct crystallization from the fraction that should contain both amides failed to reveal any asparagine whatever although glutamine was readily isolated in substantial yield. Treatment of the mother liquors by methods designed to concentrate any asparagine they might contain likewise failed to reveal this amide and gave evidence that the substance responsible for the apparent asparagine amide nitrogen has properties different from those of asparagine. It was concluded therefore that glutamine is the only substance concerned in the amide metabolism of the rhubarb plant. The marked enrichment in glutamine that occurred during culture in darkness shows that this plant possesses an amide metabolism that comes into play under the special conditions of water culture we have employed and that differs only in detail from that of the tobacco leaf. Incidental observations on the precipitation of arginine and tyrosine by mercuric nitrate along with glutamine were made, confirming observations recorded by Schulze many years ago. The demonstration that the nitrogen, which, from its behavior towards hydrolytic agents, might be attributed to asparagine, may in fact belong to some other substance is of considerable value in the interpretation of analytical results obtained by indirect methods. Isolation methods must clearly be used as a control on the indirect methods in cases where one or other of the amides is apparently present only in small proportion.

A full discussion of our results on the culture of rhubarb leaves in water and in 5 per cent glucose in darkness, and in water in light, is now in preparation. There is little doubt that this plant possesses a mechanism for the synthesis of glutamine that is exceptionally effective under certain conditions.

We secured specimens of blade tissue which, after culture for 165 hours in darkness, contained nearly 7 per cent of the organic solids as glutamine. Other samples were less efficient, and it appears that there may be considerable variation in this respect. The leaves possess an extraordinary capacity to transform the nitrogen of protein into ammonia during culture and are evidently far more tolerant of high concentrations of ammonia than those of the tobacco plant. Amide synthesis as a mechanism for the detoxication of ammonia in the sense of Prianischnikow's hypothesis has little meaning in a tissue that may normally contain as much as 16 per cent of its total nitrogen and 50 per cent or more of its soluble nitrogen as ammonia, and, while his views are very helpful in describing the behavior of the nitrogen of tobacco leaf, they shed little light on the behavior of rhubarb. Nevertheless, the main outlines of the nitrogen metabolism during culture of excised leaves are the same in both plants; protein is rapidly digested to amino acids either in light or in darkness, the amino acids are deaminized with the production of ammonia, and much of this ammonia is recombined into the form of an amide, in the rhubarb leaf exclusively glutamine under all conditions of culture.

It was hoped that an experiment in which rhubarb leaves were cultured in glucose solution would shed some light on the nature of the non-nitrogenous amide precursor. Our work with tobacco showed clearly that the presence of the products of photosynthesis is essential to the formation of this substance, and it seemed possible, therefore, that the precursor is, or is derived from, a sugar. Experiment showed, however, that glucose did not stimulate amide formation significantly under the conditions we employed although the leaves contained much ammonia and did in fact synthesize moderate amounts of glutamine. That glucose actually entered the tissues is certain, since these leaves maintained a supply of carbohydrates far higher than the controls, and sucrose synthesis was definitely increased. Furthermore there was a significant increase in the malic acid.

One of the most interesting results of these experiments was a further demonstration that leaf tissues that already contain nitrate nitrogen may become further enriched in nitrate during culture in darkness. This observation was first made in this laboratory some years ago during experiments with tobacco leaves and has been subsequently confirmed by us with the same material. Rhubarb leaves show exactly the same phenomenon; during the first 93 hours of culture, the nitrate, particularly in the blade, may increase by nearly 50 per cent of the quantity present at the start. In the later stages of culture, it diminishes again to approximately the initial quantity. The same phenomenon has also recently been found in Swiss chard and in tomato leaves by Professor McKee of Connecticut College. No adequate explanation has yet been obtained, but it seems clear that the nitrate of leaf tissues must exist in some equilibrium relationship with other substances, and that this equilibrium is to some extent reversed under the conditions of culture in darkness. The phenomenon has not yet been observed during culture in light.

The following have served as assistants in the work: Dr. Alfred J. Wakeman; Dr. Rebecca B. Hubbell; Luva Francis, secretary.

PALÆOGRAPHY

Lowe, E. A., Institute for Advanced Study, Princeton, New Jersey. *Collection and study of palæographical material required for extension of researches upon which he was engaged as a former staff member of the Institution.* (For previous reports see Year Books Nos. 9-35.)

The main task of the past year has been the completion of volume III of *Codices latini antiquiores*, which deals with the manuscripts preserved in Italian libraries from Ancona to Novara. Progress has also been made with the bibliography of volume IV, which illustrates manuscripts in the remaining Italian libraries from Perugia to Zara. During September and October of last year field work was done in Cava, Naples, Monte Cassino, Rome, Florence, Brescia, Milan, and Ivrea. During the winter months, the work of editing and revising was done at Princeton; during the spring and summer of this year it was continued at Oxford, where most of the proof-reading was accomplished. Volume III is entirely in press save for the preface. Some difficulty has been encountered in obtaining certain negatives and this circumstance has caused delay in finishing the collotype plates. However, all the necessary photographs will be procured during the forthcoming Italian journey in September. Once work on the collotypes can be continued, publication should be possible within the current year. Volume III will have the distinction of giving the first exact reproductions of the charred Herculaneum papyri, which were heretofore known only from facsimiles based on hand drawings. One of the most famous of these papyri contains an anonymous poem on the Battle of Actium. The date of the papyrus is thus fixed between 31 B.C., when the battle took place, and A.D. 79, the eruption of Vesuvius. The papyrus is thus a landmark in Latin palæography. Volume III will also have a particular interest for the student of ancient libraries, as it throws considerable light on the oldest collection of the Irish monastic foundation of St. Columban at Bobbio in North Italy. At the same time with the preparation of the two Italian volumes, steady progress has been made in examining and describing the manuscripts of Switzerland, Austria, Holland, and Belgium, which will be dealt with in subsequent volumes. This report would be incomplete without mention of the writer's sincere sense of obligation to the librarians who helped him so generously and to the staff and officers of the Clarendon Press for their constant cooperation.

PALÆONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

Merriam, John C., and Associates. *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-36.)

The program of research followed in recent years has been based upon development of a series of projects furnishing clearly verifiable data on problems having critical importance in the attempt to secure a connected history of life in western North America. Certain of the questions investigated are of world interest, and it is essential that we secure adequate data from all of the points of view which can be considered with profit: such are problems concerning the story of early man in America, the sequence of Tertiary mammalian faunas, and the beginnings of geological history as investigated at the Grand Canyon.

Much of the work done on all of the questions investigated has been carried forward by individuals, cooperating on these projects either by reason of desire to secure data bearing upon certain special situations with which they have been concerned, or because of interest in a wider vision of major problems. Much of the time of Mr. Merriam has been devoted to planning the modes of approach to new fields investigated or to correlation and interpretation of data secured.

The amount of factual material secured and made of record is very large, and much of value will come from further working over of the data obtained. The contribution toward understanding of many critical questions is being furthered by correlation of information, and especially by carrying the inquiry regarding many questions for which additional facts are needed into fields where answers might be furnished by examination of original materials in their natural setting.

In study of certain large groups of problems effort has been made to secure protection for original materials, or sites, or exposures in such manner as to open the way for further investigation in the future by students on related questions. In this connection it has proved possible in some cases to consider also the broader educational values available for public use.

Groups of exposures illustrating many of the types of problems to which reference has been made are found either in the large series of formations representing the division of later geological time known as the Cenozoic as seen in the John Day region of eastern Oregon, or in the long series of formations exposed in the Grand Canyon of the Colorado River. In both regions continuing study by specialists furnishes large return of new materials, while correlation of data adds much to our understanding of fundamental values in palæontological and geological history. In both regions it has also proved possible so to develop the work as to make significant addition to the materials of value for purposes of general education, both of investigators and of the lay public. Especially significant advance has been possible in eastern Oregon, where the Oregon State Parks Commission has secured a number of the most important sites for dedication to public use under adequate supervision.

The reports following, prepared by specialists in various fields, represent a wide range of interests but all touch in various ways the special and general questions to which reference has been made. The work done in study of problems concerning early man in America by L. S. Cressman, of the University of Oregon, Malcolm J. Rogers, of the San Diego Museum, M. R. Harrington, of the Southwest Museum, E. B. Howard, of the Academy of Natural Sciences of Philadelphia, Chester Stock, of California Institute of Technology, and Ernst Antevs makes wide and fundamental contribution to understanding of this group of problems.

Researches by Dr. H. deTerra and Dr. P. Teilhard de Chardin in southern Asia and those of Dr. G. H. R. von Koenigswald in Java represent some of the most important advances of this generation in study of the earliest known stages of human history.

In palæontology of vertebrates other than man, the investigations by Dr. Remington Kellogg, of the United States National Museum, and Dr. Chester Stock, of California Institute of Technology, include some of the most constructive contributions on the history and evolution of life obtained at this stage in development of palæontology.

In the field of invertebrate palæontology Dr. Horace G. Richards, of the New Jersey State Museum, has continued his extremely careful, and increasingly valuable, work on age determination and correlation of comparatively recent molluscan faunas.

In research concerning mainly studies in the field of geology, Dr. J. P. Buwalda, of California Institute of Technology, has continued to make definite progress in work on some of the most difficult questions in structure and history of Coast Range and Sierra geology in California. Dr. N. E. A. Hinds, of the University of California, has continued his fundamental studies on the Algonkian, rocks representing the next to the oldest of the major divisions of geological time.

Mr. Edwin D. McKee, naturalist of Grand Canyon National Park, has extended his studies of Palæozoic formations and faunas of the Grand Canyon and has published an important work on *The environment and history of the Toroweap and Kaibab formations of northern Arizona and southern Utah*.

Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, have carried out their carefully planned journey through the Grand Canyon by boat, and have made large contribution to our knowledge of the oldest series of rocks in that region, and to available data on one of the earliest chapters of earth history.

Early Man and Culture in the Northern Basin in Oregon, by L. S. Cressman

During the year a grant from the Carnegie Institution of Washington was made for investigating the problem of early man and culture in the Northern Basin in Oregon with special reference to Catlow Cave No. 1. This was supplemented by an additional grant from the Research Council of the Oregon State System of Higher Education.

Catlow Cave No. 1 is thus designated because it was the most southerly and the first to be examined of a number of caves in Catlow Valley. The

valley is in Harney County, Oregon, with its southern tip about 20 miles north of the Nevada line. It extends some 50 miles to the north from this point. Its center lies approximately 90 miles to the south of Burns, Oregon. The valley is the bed of an ancient lake, of the same period (Pleistocene and Pluvial) as Lahontan, according to Antevs.

The cave is in reality a shelter approximately 100 feet long and 60 feet deep. It is a wave cut cave produced by wave action when the water was at the top terrace (fourth in order from the lake bottom). Its elevation is between 200 and 250 feet above the present valley floor.

The work has been coordinated with the work in anthropology at the University of Oregon, and students in anthropology, especially those with a professional interest, are taken along as workmen, thus gaining field experience. This insures an intelligent and responsible body of workmen. In 1937 we used nine students under my constant supervision and direction for approximately six weeks, from June 22 to July 31.

Studies in the geology and geography of the valley with special reference to drainage into and out of the valley were made by Dr. W. D. Smith, head of the Departments of Geology and Geography, and Mr. Lloyd Ruff, instructor in Geology at the University of Oregon. In September Dr. Merriam sent Dr. Ernst Antevs at my request to make further studies with special reference to the age of the lake and the problem of stratification in the cave. Dr. Antevs' report has been filed with Dr. Merriam and his opinion is also given in the attached manuscript.

Skeletal remains. Parts of a human skeleton and one bone of a second were found in gravels. Since there was no clear stratification in the cave but only beds of different kinds of material between which the dividing lines were not clear cut, it has proved impossible to say beyond any doubt that the deposition of the bones in the gravel was a natural process, the gravel being then sealed over them. As the writer uncovered the bones, it seemed to him quite beyond any doubt that they represented natural deposition with a sand and gravel deposit of about 6 inches overlying them.

This conclusion is necessarily open to doubt in view of the character of the beds and the shallowness of covering. In September further search under Dr. Antevs' direction showed more bone fragments in gravels. We could not, however, prove that they were not intrusive, as, for example, by burial.

Lack of orderly arrangement of the bones, lack of artifacts, and the scattered condition of their deposition argued against burial.

The scattered character of the location of the bones argued against secondary burial. If coyotes or other animals had dug them up and scattered them, they would have borne the marks of teeth. Doctors Hrdlicka, Hooton, and Woodbury agree that there are no signs of gnawing, although the former and the other two disagree widely on other characteristics of the bones.

Hrdlicka gave the cranial index as 70.2 and classified the skull as belonging to the West Coast type. Hooton and Woodbury classified it as typical of the well-known early Basket Maker type and said that there was nothing to interfere with its belonging to modern antiquity. Hrdlicka classified it as an aged female while the others agreed that it was a male specimen.

When all possibilities are examined, the one which best fits the situation is that the body was deposited by wave action when it was in an advanced stage of decomposition but with the bones still covered with flesh. Wave action dismembered it and the sand and gravels covered it so that as the flesh finally decomposed, the bones were covered with sand and gravel, giving no opportunity for gravel scratches to occur. This explanation seems to be the most satisfactory of the possible ones.

The date, of course, cannot be fixed. If the body was deposited as has been postulated it must have been after the lake level was in the process of lowering but still high enough to break into the shelter in periods of storm. This would probably not be more than 15,000 years ago and likely some few thousand years later. It is entirely likely that we have here a representative of early man in the New World.

Basketry. Basketry, sandals, twine, wood, and cane products were all well preserved in the dry parts of the cave. Of these basketry alone will be discussed. This represents an excellent diagnostic type. It is a twining on a 2-ply twisted warp. Historically in baskets this type is limited to the Klamath-Modoc and Pit River areas. It is found in flexible bags, both historically and among the Basket Makers. Archæologically, it was heretofore known in only three fragments of baskets; two of these were from the early levels at Lovelock Cave; and one was from the Columbia, of much later time, and probably represented results of Klamath diffusion. We have archæological specimens from caves to the west as far as Summer Lake and near Bend. A reconnaissance party from the University has just reported specimens from a cave near Heppner in the north central part of the state. Krieger and Heizer, for the University of California, have worked over the basketry from the Humboldt Cave, which is close to the Lovelock Cave, and report that this type of basketry was found there.

The basketry has two values: first, it helps tie in our materials with the Lovelock and Humboldt Cave specimens, thus assisting in fixing a time element to ours; and secondly, it suggests that the Klamath-Modoc culture is probably but a residuum of a lacustrine culture extending throughout the vast area of southern Oregon when the now dry valleys were great life-sustaining lakes.

The basketry in the dry south end of the cave goes well back toward the bottom, while a graver and a sandal fragment were found separated from water-smoothed bed rock by less than a half inch of soil.

Projectiles. Arrows and in all likelihood *atlatl* shafts were found. No certain bows or *atlatls* were found. Our decision concerning *atlatl* shafts is based upon the diameter of the fragments and the size of the points. Of course these can never be decisive diagnostic evidence, but when compared with the variations in size of other shaft fragments and points they may be significant.

Net. A small net (about 2 feet square) was found and separately a circle of twig 3 to 4 inches in diameter. This is very like the snare pictured and described by Kidder and Guernsey from the Basket Maker cave in Utah excavated by Nusbaum. It is mentioned here because of its possible affiliation. The specimens came from the upper levels.

Pottery. Several small fragments of pottery were found near the surface. These so far lack cultural significance. Griffin of the University of Michigan Museum wrote recently after examination of the specimens that they are more suggestive of the Dismal River type from Nebraska than any other. This is, however, only a suggestion.

Thirty miles north of Catlow Cave No. 1 is Roaring Springs Cave, which was examined hastily last summer. This promises to provide better and more numerous artifacts than Catlow Cave No. 1. It is drier than the other cave, so the contents are better preserved. The excavation of this cave will be the first work of this summer's field party (1938).

We shall also do further digging in Catlow Cave No. 1 to discover, if possible, more skeletal remains.

It is important that our work should at the first opportunity be pushed east of Steens Mountain and across Malheur County toward Idaho. The second part of the field season this summer will be devoted to excavation of caves in the Summer Lake region close to Paisley and near Fort Rock.

Archæological and Geological Investigations of the Cultural Levels in an Old Channel of San Dieguito Valley, by Malcolm J. Rogers

With support from a grant by the Carnegie Corporation of New York to the Carnegie Institution of Washington, it has been possible for Malcolm J. Rogers, Chief Curator of the San Diego Museum, to organize a field expedition and undertake excavation in the San Dieguito River Valley for the purpose of cultural studies. The site chosen seemed to offer the deepest accumulation of alluvium available, and when the trench was completed, it was found to have been a fortunate choice, for a complete record of post-pluvial river history was uncovered. In addition to this the expedition was fortunate in intercepting certain unexpected archæological features.

In sinking the trench the ground was taken out in horizontal strips and, beginning at the top, after going through 2 to 3 feet of recent flood silts, a Yuman camp level with a maximum depth of 2½ feet was uncovered. This had been built upon 3 feet of lateral outwash soil of terrestrial origin. Under this was encountered a 2-foot band of boulders and sand deposited during a period of flash flooding. Beneath this was a stratum, 2 feet in thickness, which was of stream origin. It consisted of coarse sands and yellow, clayish sands. The lowest stratum was composed of boulders and sand strata which attained a thickness of 7 feet at the entrance of the trench. This formation rested on a Tertiary sandstone into which a Pleistocene channel had been cut.

The lowest stratum was also implementiferous, and most cultural material consisted either of factory débris or of transported items. In the upper third, however, was found a degraded camp level which produced many whole implements. This streak was followed laterally both ways until cave-ins made it too dangerous to do further work. Stream-transported implements occurred to the very base of the stratum and on the contact with the Tertiary surface. These are probably Phase I or II San Dieguito tools derived from camps farther up stream. The camp level matter is all

Phase III material, as well as that found in the corresponding horizon in mid-channel residual humps.

Splendid examples of solifluction were found throughout the main trench section, probably the first found in the New World. San Dieguito implements were even found on top of the Yuman horizon, being the result of lateral outwash.

Researches of M. R. Harrington

During the period July 1, 1937 to June 30, 1938, one research project was undertaken with funds made available by the Carnegie Institution of Washington. This was an archæological reconnaissance in Lake County, California, to investigate a report that Folsom projectile points had been discovered on a certain site in Clear Lake Park and that other known types of early stone implements had been found in the vicinity. The report was made by Mr. Chester C. Post, retired merchant and amateur archæologist of Berkeley, California, a member of the Southwest Museum, Los Angeles.

The month of April 1938 was spent in this investigation by Mr. M. R. Harrington of the Southwest Museum, with Mr. S. M. Wheeler as assistant, aided by the volunteer services of Mr. and Mrs. Post, and for a short time by Mr. Elden Baylard, a local man employed as laborer.

The region of Clear Lake, in Lake County, is of volcanic origin, with one large extinct volcano, Mount Konocti, rising nearly 3000 feet from the southwestern shore, and a number of obsidian deposits, especially near the southeast end of the lake. Most of these have been worked by ancient peoples from remote prehistoric times. Clear Lake is nearly 20 miles long and its waters are fresh and potable.

Archæologically the country is very rich, and private collections are numerous. An inspection of these revealed a number of types of implements varying greatly in form, finish, and degree of patination, suggesting the presence of different cultures in the district at various times. An archæological study of the whole region, working back from known historic village sites of the present Pomo Indians, should prove of great interest and might establish a guide to the sequence of cultures in northern California.

Although the collections contain a few points that suggest Folsom styles, true Folsom points were seen only among the material collected by Mr. Post on the site he reported, situated on Borax Lake in Clear Lake Park. There are six of these, including one perfect specimen of yellow chalcedony. The others are all obsidian.

Borax "Lake" is a lake bed situated in a landlocked basin, possibly an old crater, among the hills about half a mile northeast of the southeast end of Clear Lake. At the present time the water, very saline, remains only in the northwest end; but it is plain that at one time it stood at a considerably higher level. The lake bed is about $1\frac{1}{2}$ miles long by $\frac{1}{2}$ mile wide. The site is situated on a low terrace just east of the southeast, or dry, end of the lake bed, above the level of the highest traceable former shore line of the lake.

A young walnut grove occupies the site, and the ground had been recently plowed, exposing an area of blackened soil, roughly 300 feet in diameter, strewn with flakes and fragments of obsidian and other materials used by the former inhabitants. A careful search of the surface revealed three more typical Folsom points, together with scrapers, graters, and other implements constituting almost the entire Folsom complex of Roberts. In addition to these were many points and other objects characteristic of the Lake Mohave complex as published by the Campbells, including both Silver Lake and Lake Mohave types, and a form of wide-shouldered, narrow-stemmed point we have named the "Borax Lake" type. This, reported only sporadically elsewhere, seems especially abundant on this site.

A few small test holes with a trowel revealed the fact that human indications continued quite a distance below the surface; and realizing the importance of a site containing Folsom artifacts on the surface, we decided upon a trial trench. Obtaining permission from Captain Harry Wallis, manager of Clear Lake Park, we started our trench between two rows of walnut trees in the middle of the area that had yielded the largest number of Folsom points. This trench, 6 feet wide, was divided into yard squares for convenience in recording. By the end of April we had excavated, with small trowels, 30 feet of this trench, running from 7 to 8.5 feet in depth, with tests down to 10 feet, and had found underground 251 artifacts, exclusive of chips and flakes.

We found that the black soil containing most of the artifacts ran about 5 feet 4 inches deep; below this flakes of obsidian and occasional artifacts continued down to more than 8 feet in places, mixed with the yellow subsoil.

To summarize briefly our results: Strictly Folsom objects were found only on the surface, although certain types of scrapers that are common to both Folsom and Lake Mohave did appear underground. Moreover, Silver Lake points and other objects belonging to the Lake Mohave but not to the Folsom series were also found below the surface. No projectile points of any kind appeared below 40 inches, except the base of a Folsom-like form at 59 inches, which may have reached its resting place through a rodent- or root-hole from above. A crude metate appeared at 56 inches; a short cylindrical pestle-like implement was found at 35 inches, and a mortar fragment was unearthed at 46 inches, in the bottom of a disturbed area. In the lower levels a few heavy scrapers and choppers were found.

Our tentative conclusions, based on the small amount of work done, may be stated as follows:

A. People of the Folsom culture visited the Borax Lake site and camped thereon, presumably about the same time as the Folsom occurrences in New Mexico and Colorado, where we know they were associated with mammals of Pleistocene type, now extinct.

B. Previous to the arrival of the Folsom people, the Borax Lake site had been inhabited long enough to accumulate gradually more than eight feet of soil mixed with human artifacts.

C. On this site the Lake Mohave and Borax Lake cultures are older than Folsom, but continued until the arrival of the Folsom people; in short they are both earlier than and contemporary with the Folsom culture.

D. The crude grinding slab or metate and the short cylindrical pestle are older than Folsom on this site.

E. The crude bowl-shaped mortar may be older than Folsom, but its relation to the deposits on this site is uncertain.

F. Massive choppers and scrapers appearing in the lower levels of the deposit may represent a culture older than Folsom, Lake Mohave, or Silver Lake.

As mentioned, the above conclusions are tentative only. A great deal more of careful stratigraphic work is needed on this important site before final conclusions can be made.

Researches of E. B. Howard

In the course of one of Dr. Merriam's recent trips to St. Augustine he had an opportunity to examine some fossil vertebrate material which was on display at the filling station of a Mr. Ed Johnson at Bon Terra, St. John County, Florida, about 29 miles south of St. Augustine just off the shore road.

Believing that there might be some association of these vertebrates with man, Dr. Merriam asked the writer to investigate the site a little further. This he did in February in company with Mr. Malcolm Lloyd of Philadelphia.

Unfortunately it had been raining heavily for several days before and during the time we visited the site, so that the place from which the bones had come was completely covered with water. The site is a low field between the road and the Inland Waterway Canal. The field is about $\frac{1}{4}$ mile wide at the point where the bones were found by one of Mr. Johnson's sons, who has since died.

The site is apparently the same general locality mentioned by Hay,¹ from which a collection had been made by a Mr. Fred R. Allen some years ago. Hay mentions the following specimens in the collection: *Mammut americanum*, *Equus* sp., *Myiodon harlani*, *Terrapene antipez*, *Elephas columbi*, all of which he regarded as belonging to "some part of the first half of the Pleistocene, probably the first interglacial."

The site from which Johnson secured his material is in about the middle of the marshy field, which is composed of muck resting on a grayish sand which in turn rests on a coquina. It was too wet to do more than probe around the hole left by the previous digging, and the result was that no proper investigation could be made. The specimens which Johnson is said to have dug from this spot, and which were on exhibit at the filling station, included ground sloth, mastodon, mammoth, horse, tapir, and camel. There was also from the same place an object that resembled a bone awl, but which turned out not to be an artifact. Whether it was the spine of some fish or other form from the sea could not be determined.

The site appears to be a continuation north of the Melbourne and Vero beds, and the faunal assemblage seems to be much the same. It would be worth while to make a further investigation at some time during a dry season.

¹ Oliver P. Hay, *The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°*. Carnegie Inst. Wash. Pub. No. 322 (1923).

Studies on the Climate in Relation to Early Man in the Southwest, by Ernst Antevs

These studies brought important results during the past year.

In the summer of 1937 an unusually heavy flood of the Whitewater Wash in the southeastern corner of Arizona deepened and widened the arroyo, exposing new profiles, many bones of extinct mammals, and several buried sites of the Cochise culture. The fossil bones represent chiefly mammoth, sloth, dire wolf, horse, and bison, all extinct. These bones are sufficiently numerous and important to induce Dr. Chester Stock to plan a collecting trip to the Whitewater arroyo this fall (1938).

The Cochise culture, which is studied in collaboration with the Gila Pueblo Archeological Institution at Globe, Arizona, occurs in direct association with the fossil bones as well as in strata correlated with the bone-bearing beds. It is one of the oldest records of man in North America.

Part of the charcoal found with the Cochise artifacts at the Double Adobe site has been identified by Dr. R. W. Chaney as hickory. In our day the nearest occurrence of hickory is some 800 miles distant in the mountains of northeastern Mexico and in eastern Texas. In a region with high temperature and great evaporation the hickories grow in wet woods, along streams and on the borders of swamps. Unfamiliar with the great moisture requirements of the hickories, the writer at first concluded that the erosion surface underlying the artifact-bearing sand, as well as this sand itself, indicated a dry stage, as does the modern arroyo cutting and the sand and gravel on the arroyo floor. The presence of hickory, however, is conclusive evidence that the climate then was subhumid to humid and that there was a permanent stream in the valley. The main channel of the old stream may have been lower than the floor of the present arroyo, the sand being a flood-plain deposit. Therefore the artifact-bearing sand bed dates from the Pluvial period, as does the superimposed laminated clay, which was deposited in a permanent lakelet dammed perhaps by beavers.

Much search has been made for irrefutable field evidence of contemporaneity of man with the highest stand of the large Pluvial lakes of the region, especially Lake Cochise, which occupied the Willcox basin.

The climatic variations during the postpluvial age, or the past 10,000 years, have been studied in so far as they are revealed by different kinds of sediments and by the intercalated stages of erosion. Conditions and fluctuations during the past 2000 years are being dated with the help of potsherds.

Studies of Geology, Palæontology, and Archæology Relating to the Origin of Man as It May Be Recorded in the Himalayan Region of Asia, by H. deTerra

These studies have been supported in part with financial aid from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Measuring the Age of Man in terms of cyclic geologic processes has always been a subject fascinating to both geologists and archæologists. Unfortu-

nately we know too little of such processes outside the glaciated regions to work out a stratigraphic scheme which might be applied to wider areas, and yet this would be the solution to many important problems concerning Ice Age and prehistory of man. Following the writer's previous work in India, it was thought that the Ice Age chronology as worked out by him in the Himalayas might well provide us with means by which we could visualize and measure the evolution of Stone Age man in Asia. Indeed, the geological evidence in India had clearly pointed to a correspondence of glacial with pluvial stages, the latter being characterized by thick, coarse-grained sediments. These previous studies had also disclosed that the Paleolithic of India was associated with a system of terraces in which were reflected both a climatic and a diastrophic cycle. Although no human fossils had come to light, it was evident through thousands of stone implements, found in terraces and with fossils, that early man in India dated back to the second Himalayan glaciation. This, to all appearance, represents the Mindel glaciation of Europe. From that time on Stone Age records were traced in India up to the appearance of the first man-built monuments, which in Kashmir probably date back to at least 6000 B.C.

These results, which have been submitted for publication to the Carnegie Institution, warranted a new investigation of this subject in countries lying to the east. It was hoped that this might lead to correlations with China and Java, where similar studies have more recently led to new discoveries of fossil man.

The expedition of this season led to Burma and Java and lasted from October until the end of May of this year. Once more it was possible to obtain the cooperation of Dr. Teilhard de Chardin as palæontologist. This work was carried out jointly with the Carnegie Institution of Washington, the Academy of Natural Sciences at Philadelphia, and the Peabody Museum of Harvard University. The last mentioned shared with the American Philosophical Society the major expenses for this expedition. Dr. H. L. Movius from the Peabody Museum at Harvard was in charge of the archæological work.

Under the writer's direction field work was carried out in Burma from November 1937 until March 1938. Following this, the expedition members proceeded via Malaya to Java, where they established contact with the work which Dr. von Koenigswald is doing on behalf of the Carnegie Institution.

Geological and palæontological results. Our main field of investigation lay in Upper Burma, in the Irrawaddy Valley, and in the Shan States to the east of it. The geology of this region is similar in many respects to that of the Himalayan foothills. As in India, the formation of terraces succeeded the deposition of an early Pleistocene formation from which we collected a great number of vertebrate fossils. These indicate that Burma was at that time linked with India and South China by a great migration route of mammals which permitted faunistic interchange between these regions and the East Indian archipelago, which at that time was still part of the continent. In the early Pleistocene beds two phases are represented, of which the older was a period of heavy rainfall. A second such "pluvial" stage is

revealed by red boulder gravels which overlie the older beds disconformably. A third and fourth pluvial finally are recorded by younger gravel terraces which in composition and number correspond to the terraces attributed in India to the third and fourth glacier advances. The intervals between these stages are indicated by erosional breaks in the terrace sequence, and especially by the formation of certain fossil soils indicating dry climatic intervals.

This stratigraphic pattern of the Quaternary of Burma shows that the northern tropical belt of Asia responded to a climatic cycle similar to that which is known to have existed in northern latitudes. This feature opens for the first time possibilities of covering under a single stratigraphic and physiographic scheme the Quaternary history of the whole south and central Asiatic mass. So far as South China is concerned, its applicability appears to be assured by the fact that in the Yangtse Valley terraces and soil formations occur similar to those in the Indian and Burmese river tracts. Also the highlands connecting these countries share extensively in the same fossil records of Quaternary time, as was revealed by our expedition through cave excavations. This uniformity of geological events during the Ice Age must be of interest to paleontologists and archaeologists alike. Both are dealing with studies of ancient life which can now be visualized more clearly than ever, as having been determined by the impacts of climate and mountain making such as are revealed by great geographical changes in the lowlands bordering High Asia.

Archæological results. Implements of ancient man were found at many places in Upper Burma, chiefly in gravel terraces but also near the surface under a slight cover of wind-blown sand. The latter has covered up temporary settlements of people using polished stone tools and handmade pottery. The older gravels contain locally great numbers of crude stone tools; most of them are waterworn, and yet in some cases they are associated with their contemporary fauna, which is of middle Pleistocene age. In some respects these artifacts resemble the Indian "Soan cultures," which are characterized by the absence of hand axes. But the Burmese Paleolithic is much cruder in workmanship than the Indian; for one thing, it lacks any association with hand axes. This and other significant typological features appear to connect it with the oldest Chinese culture of Choukoutien as well as with the Old Paleolithic of Java. It is obvious that such archæological relationships reflect a new Paleolithic tool complex different from anything which either Europe or Africa has to offer. But it is to be noted here that the Folsom culture of North America has its typologic parallels with this southeast Asiatic Paleolithic. It seems therefore that Burma was situated near a center of dispersal from which Old Paleolithic cultures migrated during the middle and upper Pleistocene. Some 250,000 to 350,000 years ago Burma lay within a cultural circle of extinct races which to all appearance did not belong to the Peking-Java Man stock but to a very early Neanderthaloid species.

Such a conclusion was reached only after we had visited Java. Here, we had the most welcome chance to study at close range the geological and

palæontological problems connected with the famous fossils of extinct man. With Dr. von Koenigswald as a guide we could not fail to appreciate the work that is being done by him and his Dutch colleagues. In view of the association of certain Paleolithic tools found here with the Neanderthaloid Solo Man, and considering the absence of implements in the Trinil beds which contain the remains of Java Man, it would seem as if the Old Paleolithic is here not to be connected with the most ancient human fossils. Another result of our visit was the recognition of certain geological features in the Quaternary of Java which make correlations with the mainland of Asia less readily available than was at first anticipated.

European study tour. In view of the new information received from these Asiatic studies it seemed imperative to compare certain outstanding stratigraphic and archæological features with records of early man in Europe. An opportunity presented itself for a study tour which led to the classic region of the Somme Valley in France, to the Rhine Valley, and to various sites in Germany where the geological data are especially clear. The general impression received from these studies was that in central Europe the geological dating of early human remains is greatly hampered by the fact that most of them are found away outside the glaciated tracts, where terraces or gravel deposits cannot be readily connected with the ice advances. This introduces an element of uncertainty inasmuch as the palæontological method of stratigraphy is by itself insufficient for dating purposes. A closer tie with the glacial cycle is required, and this could be achieved only if detailed inquiries were made in areas where Alpine or continental glaciers have left their records. Despite the extensive work that has so far been done in central Europe, it would seem that here lie research fields of a very promising nature.

Anthropological and Historical Studies Relating to the Earliest Evidence of Man, by G. H. R. von Koenigswald

These studies have been supported with financial aid from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The researches on the lower Pleistocene Djetis and the middle Pleistocene Trinil fauna have been continued. A large collection of fossils from these layers has been made, especially from the area north of Solo, and a remarkable number of species new to these faunas has been found, especially of rodents (*Lepus* 2, *Rhizomys* 1, *Rattus* 1) and carnivores (*Canis* 2, *Ursus* cf. *malayanus* and *U.* cf. *kokeni*, *Viverricula* 1, *Paradoxurus* 1, cf. *Herpestes* 2, div. spec. indet.). Furthermore, we found *Tragulius* and a new species of a big antelope, and a number of fine teeth of *Hylobates* and *Simia*. Some of the new species seem to be identical with species from southern China, and the new finds prove more than we expected the influence of the Chinese "Sinomalayan" fauna.

The most important finds are remains of *Pithecanthropus*, of which a skull cap and a mandible were mentioned in the last report. In addition, a few isolated teeth have been found (not yet described), some of them unworn and in perfect condition. A big upper molar shows traces of an accessory

cuspid near the protocone, a feature also observed in *Sinanthropus* and *Australopithecus*. The crown pattern of unworn lower molars resembles much those of *Sinanthropus* except that the wrinkles are less complicated. But in the *Pithecanthropus* teeth the entoconid seem to be less developed, so there is no important difference between these and the corresponding teeth of an anthropoid.

The Modjokerto area, visited twice, has yielded no special new finds. In the Southern Mountains (Goenoeng Kidoel) more palæolithic stone implements have been collected, bringing up the whole collection to more than 3000 specimens. In the rock fissures more teeth of anthropoids (*Simia*, *Symphalangus*, *Hylobates*) have been found, and traces of a large tapir (cf. *Megatapirus augustus* Matthew and Granger, from southern China).

A special research for stone implements has been made on the old river terraces along the Solo River north of Ngawi. A few primitive implements have been collected, but these upper Pleistocene gravels have yielded no hand axes.

D. P. Erdbrink has discovered a new area with palæolithic implements south of Soekaboemi, western Java, of which we made a good collection.

In February, after the Prehistoric Congress held in Singapore, a trip was made through Malakka and Siam to continue the research on fossil mammals from the Chinese drug stores. Interesting material of the Pontian *Hipparion* fauna (including *Hyænarcos* and a big *Anchitherium*) and of the Pleistocene cave fauna (fossil orang; two teeth of fossil man) could be acquired.

In April Dr. H. deTerra, Dr. Teilhard de Chardin, and Dr. H. Movius visited Java. A joint excursion through Java was made, especially to the sites where fossil man has been found, and to the sections which show the stratigraphical sequence. In July Professor A. Heim-Zürich visited the new *Pithecanthropus* site.

In collaboration with Dr. H. Movius (Harvard University) the palæolithic culture of Patjitan will be described.

Researches of Remington Kellogg

In connection with studies now in progress on the cetotheres, the precursors of the living whalebone whales, the types of nearly all the known Tertiary forms have been critically examined. Additional cetothere material, representing several different types, has been obtained during the past year from the Miocene Calvert formation in Maryland and Virginia. Nevertheless, the available material is still inadequate for detailed studies on the skeletal construction of some of these extinct whales. It is expected that continued field work will supply the necessary material. During the past year cetotheres described by E. D. Cope have been loaned to the writer for study by the Academy of Natural Sciences of Philadelphia and the American Museum of Natural History. In the interim between the Preliminary Whaling Conference held at Oslo, Norway, in May, and the International Conference for the Regulation of Whaling held at London, England, during June 1938, fossil, subfossil, and Recent cetacean material was examined at Stockholm, Uppsala, Copenhagen, Sandefjord, Bergen, London, and Edinburgh.

Since one of the objects of these palæontological studies has been to elucidate how the characteristic skeletal and cranial peculiarities of the several families of whalebone whales were acquired, each structural condition has been examined in the light of the existing knowledge of the successive types that have made their appearance in the course of geologic time and of the progressive ontogenetic changes that can be observed in fetal skulls of mysticetes. A cursory examination of these cetothere skulls demonstrates that the original relations of the bones that comprise the braincase have been altered by the slipping of one bone over another, but more precise studies are required to discover the factors involved in this evolutionary process whereby the skulls of the members of the several lines of development represented among the whalebone whales have been remodeled in different directions. By employing a pantograph it has been possible to obtain true orthographic projections of the cranial architecture of these cetothere skulls. Since these are all drawn to the same scale, it has facilitated examination of the directions in which the skulls of these cetotheres have been altered by this telescoping process. Detailed comparisons of the skeletal and cranial peculiarities of these cetotheres have demonstrated the importance of an adequate series of fetal skulls of Recent whalebone whales for the interpretation of puzzling structural conditions. Through the active cooperation of the United States Coast Guard whaling inspectors, Mr. Marc Lagen, manager of the American Pacific Whaling Company's stations in Alaska, and the officials of the Western Operating Company's antarctic floating factory *Ulysses*, additional material of considerable importance to these cetacean studies has been acquired by the United States National Museum, including the fetuses of several whalebone whales, and a skull of the antarctic right whale. Illustrations for some of this cetothere material have been made by Mr. Sydney Prentice.

Researches of Chester Stock

During the past year Carnegie Institution of Washington Publication No. 487 has been completed with the printing of four reports in addition to those indicated in the Year Book for 1937. These articles are listed in the bibliography.

Among studies of Tertiary mammalian faunas and horizons of western North America are listed investigations now complete or nearing completion. Paul C. Henshaw has completed his study of a late Miocene or early Pliocene mammalian fauna from the Avawatz Mountains, San Bernardino County, California. Among the several faunal stages known from the Mohave Desert area, this assemblage appears to be most closely related to the Ricardo. The significance of the Avawatz fauna lies largely in the fact that it aids in establishing the age of some important diastrophic events in this section of the Mohave Desert, south of Death Valley. Mr. Henshaw's report is being submitted to the Institution for publication. A study of the fossil rodents in the Avawatz fauna by Dr. R. W. Wilson is now under way. J. F. Dougherty has completed a study of the skull and skeletal material of *Paratylopus cameloïdes* from the John Day deposits

of eastern Oregon. This paper and one by Chester Stock on complete *Hipparion* remains from the Thousand Creek beds, Nevada, will be submitted shortly for publication.

The Central Washington College of Education at Ellensburg, Washington, was visited this year and through courtesy of Professor G. F. Beck the important collections of fossil mammals from the Ellensburg and Ringold formations were examined. Opportunity was also afforded to see the occurrence of some of this material in the field. Age of the Ellensburg and Ringold formations has been under discussion for some years and determination of the age of the Ellensburg is of special interest to students of the Tertiary geology of eastern Oregon and eastern Washington in view of the relationship of the Ellensburg to the Columbia lavas.

Studies relating to the Quaternary period include continuation of the detailed investigation of the fauna obtained in Pit 10, in which human remains are known to occur, at Rancho La Brea. The report on the birds in this assemblage by Dr. Hildegard Howard and Dr. Alden Miller is practically complete. Examination of the mammalian fauna has focused attention upon the Canidæ of Rancho La Brea. It was found necessary to review in detail the Pleistocene Canidæ to establish a basis on which the characters of the dogs in the Pit 10 assemblage might be properly evaluated. This survey brought to light a number of skulls of the timber wolf, not heretofore recognized as occurring in the Los Angeles Museum collections. The material furnishes valuable information which was not available to J. C. Merriam when he published his memoir on the Canidæ of the brea deposits in 1912. A survey of the Pleistocene coyotes from Rancho La Brea has made available a single jaw of unique character. This was described by Chester Stock.¹

At the request of Harold Gladwin and E. B. Sayles, the Gila Pueblo at Globe, Arizona, was visited to examine a collection of mammalian remains obtained by the Gila Pueblo in the course of excavations in southeastern Arizona. The mammalian materials come from deposits containing a human record and it is, therefore, of significance to determine the relationship of this assemblage to known mammalian faunas of the later Quaternary in the Southwest. Opportunity was afforded to discuss the nature of the occurrence and the climatic implications with Dr. Ernst Antevs. Plans were laid for an examination of the field relationships and for further collecting of mammalian remains in the Quaternary desposits of Sulphur Springs Valley, Arizona.

At the request of Dr. Merriam two visits were made to the site of the San Dieguito culture, which is being investigated by Malcolm Rogers of the San Diego Museum. Opportunity was afforded to discuss with Mr. Rogers the problem of early man as presented by the excavations and the results obtained at the San Dieguito River localities.

On July 31, 1938, John L. Ridgway retired from active duty as scientific illustrator for the Carnegie Institution of Washington and the California Institute of Technology. A tribute to Mr. Ridgway has been published else-

¹ Chester Stock, Bull. Southern Calif. Acad. Sci., vol. 37, pp. 49-51, pl. 10 (1938).

where.¹ Mr. Ridgway's career has been a long and distinguished one. He was early associated with the Carnegie Institution as adviser in matters of illustration. During the past eighteen years he has been in the employ of the Institution as scientific illustrator and in this period has been responsible not only for countless numbers of drawings, but also for the high standards of illustration shown in the palæontological papers and monographs published particularly by the Institution. His recently published book, *Scientific illustration* (Stanford University Press, 1938), should find wide use among authors and others interested in the creation and reproduction of fine illustrations. David P. Willoughby is now employed as scientific illustrator.

Studies on Pleistocene Mollusks, by Horace G. Richards

Three reports have been prepared which are based upon field work made possible by previous grants from the Carnegie Institution of Washington (see bibliography):

1. A preliminary report has been written in collaboration with Professor B. F. Howell, of Princeton University, on the Pleistocene of the Champlain Sea of Vermont. Eight species of mollusks were recorded.

2. A report has been prepared on the Pleistocene fresh-water mollusks of Louisiana and Mississippi. The field work for this report was completed in September 1936, and was carried on in cooperation with some work done under the auspices of the Geological Society of America. The report lists twenty-three species from seven localities.

3. The final report on the marine Pleistocene of Florida has been published. This work was aided jointly by the Carnegie Institution and the Geological Society of America.

With the aid of an additional small grant from the Carnegie Institution, the writer has been able to continue his studies on Pleistocene mollusks during 1938. Much of this work has been done at the Academy of Natural Sciences of Philadelphia. In addition to the studies on material which the writer had personally collected on previous occasions, he was able to devote some time to several small collections which had been sent to him for determination. Several of these collections had been taken from archæological sites and it is hoped that the study of the shells may help in the dating of the respective sites. The complete results will appear elsewhere; the following is a summary of the most important collections studied:

A large collection of Pleistocene marine mollusks from North Creek, Florida, collected by the writer in 1937, was studied. A correlation with the Pamlico formation is suggested.

Pleistocene mollusks from the Gulf Coast of Texas collected by Dr. W. Armstrong Price and the writer in 1936, 1937 and 1938 were studied. The dating and correlation of the material is discussed in a report to be submitted to the Geological Society of America.

A small collection of land and fresh-water shells submitted by Dr. Ernst Antevs from archæological sites in southern Arizona included the following: *Helisoma trivolvis* (Say), *Succinea avara* Say, *S. grosvenori* Lea, *Lymnæa palustris nuttalliana* Lea, *L. caperata* Say, *L. obrussa* Say (?), and *Sphærium*

¹ Chester Stock, *Science*, vol. 88, pp. 145-146 (1938).

aureum Prime. All the species are to be found living in the same vicinity today.

A collection of shells was submitted by the Missouri Resources Museum (Jefferson City, Missouri) from an archæological site in a cave near Scotia, Crawford County, Missouri. The following were identified: *Polygyra zaleta* Binney, *P. inflecta* Say, *P. appressa* Say, *P. monodon cava* Pilsbry and Vanatta, *P. profunda* Say, *P. elevata* Say, *Anguispira alternata* Say, *Lymnæa obrussa* Say, *Campeloma subsolidum* Anthony, and *Sphærium striatinum* Lamarck. Since all these species are known to be living in Missouri today, a recent age is suggested for the site.

A collection of shells from Irene Indian Mound near Savannah, Georgia, was studied. The material was submitted by Dr. V. J. Fewkes, Supervisor of the Irene Mound W.P.A. Project. Marine, brackish, and fresh-water species were included. A report is to be submitted to the Irene Mound Project.

The Pleistocene mollusks obtained by Dr. Richard F. Flint on the Boyd Arctic Expedition to Greenland in 1937 were submitted to the writer for study. The material contains only ten species and is apparently of late Wisconsin or post-Wisconsin age. A comparison of these shells with material collected by Captain Bob Bartlett from the Recent seas off northern Greenland suggests that the Pleistocene mollusks lived in somewhat less saline waters. A brief statement on the collection has been submitted to Dr. Flint for inclusion in his report on the geological results of the expedition.

The study of a small collection of fossils from Pleistocene deposits on Castor River, 15 miles north of Hawk Bay, Newfoundland, collected by Dr. Girard Wheeler of Rutgers University (New Brunswick, New Jersey) added *Serripes grælandica* Beck and *Buccinum tenue* Gray to the list of Pleistocene mollusks from Newfoundland.

A collection of marine shells from a Maya burial near Chichen Itza, Yucatan, submitted by Mr. H. J. Boekelman of the Louisiana State Museum, contained the following: *Polinices duplicata* Say, *Crepidula fornicata* Linné, *Modulus modulus* Linné, *Neritina virginea* Linné, *Oliva sayana* Ravenel, *Olivella nivea* Gmelin, *Marginella apicina* Menke, *M. labiata* Val., *Thais hæmastoma floridana* Conrad, *Cerithium muscarum* Say, *Littorina anguilifera* Lamarck, *Vermicularia spirata* Philippi, *Fasciolaria tulipa* Linné, *Columbella mercatoria* Linné, *Conus sticticus* Adams, *Cantharus cancellaria* Conrad, *Chione cancellata* Linné, *Arca occidentalis* Philippi, *Chama* sp., *Anomalocardia cuneimeris* Conrad, *Rangia flexuosa* Conrad, *Cardita floridana* Conrad, *Mytilus exustus* Linné, *Pedalion alata* Gmelin.

Researches of J. P. Buwalda

The mapping and study of the complex fault system bounding the San Gabriel Range on the south was extended somewhat farther eastward from the Mount Wilson section of the range, and the relation of the Raymond fault, which bounds the Pasadena block on the south, to the main fault system in the area where it joins that system was more clearly defined. Owing to the large accumulation of erosional waste swept out of the canyons of the mountain front and deposited as alluvial fans along the base, the

attitudes and structural relations of the individual faults are usually difficult to determine, but the fault pattern is very significant with reference to the question of horizontal or strike-slip displacement, touched upon in an earlier report. Most of the persistent and long faults of southern California, especially those that trend northwest-southeast, have experienced extensive horizontal movement. The fault system along the south face of the San Gabriel Range has clearly suffered large vertical or dip-slip displacement. The absence of important horizontal dislocation, previously inferred, is very fully corroborated by more recent work. The pattern, in addition to being very complex, contains many important faults which make large angles with the trend of the system, contrasting with the general linearity or near parallelism of the component faults in the strike-slip fault zones. Locally the entire fault system along the base of the range turns abruptly, giving rise to strong salients and recesses in the front. The pattern therefore seems scarcely to admit of important horizontal displacement. The Raymond fault joins the main system not in a clean junction but in a zone of subparallel faults rather widely spaced, some of the blocks in which have been uplifted some distance with the main San Gabriel block and well above the San Gabriel Valley to the south. The pattern of the Raymond fault likewise involves sharp-angle deviations and striking salients, and it likewise is difficult to interpret as other than a dominantly dip-slip fault of reverse character on which the horizontal displacement, if any, has been so inconsiderable as not to affect the fault pattern. The conclusion that some of the active faults of southern California are experiencing entirely different types of dislocation from those which have usually been regarded as the more active and more culpable in originating earthquakes has an important bearing on the whole question of the mechanics of the deformation of the region and the actual genesis of the recurrent shocks.

Several years ago, at the suggestion of Dr. Arthur L. Day, several experiments testing geophysical methods for determining crustal structure were performed and the results published. In the course of this study, in collaboration with Dr. B. Gutenberg and Mr. H. O. Wood, velocity of seismic waves in the granites of the Yosemite region was measured, the investigation being supported with funds made available by the Carnegie Institution of Washington. In continuation of this study, through the encouragement largely of President Merriam and his interest in expanding our knowledge of the superb natural features of Yosemite Valley, an investigation was begun to determine the thickness of the alluvial fill in the valley and therefore the actual form of the bedrock trough excavated by the glaciers which now constitutes the valley. This research, supported largely by the Geological Society of America but also in part with funds and equipment contributed by the Institution, was completed in the field in September 1937, and the results are now nearing completion for publication. This seismic reflection mode of attack revealed the rather astounding fact that the depth of the alluvial fill in the portion of the valley near the government headquarters reached a maximum of nearly or quite 2000 feet, indicating that the depth of the valley seen by the visitor to the Park, about 3000 feet, is actually only about three-fifths of the real depth of the glacial trough.

A second surprising fact discovered is that the floor of this trough appears to rise about 1000 feet in going downstream some 3 miles from near the government headquarters and Camp Curry to the neighborhood of El Capitan. It appears also that the fill in the valley is not a single unit, but consists of three bodies of material possessing quite distinct velocities of transmission for the dynamite-generated artificial earthquake waves utilized in this type of geophysical investigation.

Researches on Algonkian Formations, by Norman E. A. Hinds

During April 1938, a brief trip was made to southeastern California for the purpose of further studying Algonkian deposits in the desert ranges southeast of Death Valley. This series of sediments very possibly was once continuous with that at Grand Canyon and, after deposition, suffered a similar amount of deformation probably during the Grand Canyon orogeny. The California strata apparently were deposited much closer to the shore line than were those at Grand Canyon. Some search for fossils did not yield any animal remains. Supposed algal structures are abundant in the limestones. Deformation of the crust to form the basin in which the Grand Canyon and southeastern California Algonkian deposits were laid down probably marks the initiation of the southern part of the Cordilleran geosyncline as a great basin of deposition.

Work on the report concerning the Grand Canyon Algonkian was continued during the year by my assistant, C. E. Van Gundy, and myself.

Researches on Paleozoic Stratigraphy in Grand Canyon, by Edwin D. McKee

Detailed stratigraphic studies of the Paleozoic formations in Grand Canyon have been continued during the past year. Many important data relating to the history of the Cambrian and Devonian rocks were obtained during a boat trip down the Colorado River through the Grand Canyon. This trip was made in the fall of 1937 under the leadership of Dr. Ian Campbell. Important new information on the history of certain of the higher formations has been obtained, largely through a series of trips by foot down from the Canyon rims.

In the Cambrian rocks of Grand Canyon 35 collections of fossils, representing various horizons and localities between Grand Wash Cliffs to the west and Marble Canyon to the east, have been made. These specimens were examined by Dr. C. E. Resser, who states that a majority represent undescribed species. He has recognized in the collections 12 genera of trilobites, 8 of brachiopods, and 1 each of coral, cystid, gastropod, and sponge, all of Lower and Middle Cambrian age.

By tracing individual members of the Cambrian formations westward along the Colorado River, it has been possible to demonstrate certain stratigraphic relationships heretofore open to question. The two most significant of these are as follows:

1. The base of the massive limestone units (Muav) rises stratigraphically toward the east by virtue of a lateral transition in type of sediment, present in successively higher members from west to east.

2. The so-called "snuff dolomites," which have generally been considered

good marker beds in the upper part of the Bright Angel shale, are at different horizons in different localities and each is of relatively limited distribution. They appear to represent lateral transition stages at various horizons between massive limestones and green shales.

In the Devonian strata of western Grand Canyon it has been found practical to recognize in the formation five subdivisions based on lithologic and physiographic character. These units can be recognized over a number of miles, so should assist materially in determining detailed stratigraphic relationships across the entire area. The eastern margin of continuous Devonian beds in Grand Canyon has been found to extend at least to the eastern side of Great Thumb Point and probably to the vicinity of Garnet Canyon.

In the Supai formation statistical studies made of the angle and dip of laminae in cross-bedded units have introduced a new complexity to the problem. Some hundreds of readings made over a wide area have shown little variation from a regional south-southeast dip among these laminae, indicating a source somewhat west of north. This apparently conflicts with conclusions as to the source of the sediment that have been drawn from the increase of limestone beds westward and from the presence of relatively coarser red beds, supposedly of the same age, east of Grand Canyon.

Geological Studies of the Archean Rocks at Grand Canyon, by Ian Campbell and John H. Maxson

The season just passed saw the successful accomplishment of a major event in Archean research in the Southwest; namely, the traverse of the entire Grand Canyon section and mapping of all Archean exposures.

Previous field work on the Archean rocks of the Grand Canyon has been carried out from fixed camps in the Bright Angel Quadrangle. The Vishnu schist of Walcott,¹ exposed in the Inner Gorge south of Vishnu Temple, was described by him as consisting of micaceous schists and quartzites cut by granitic dikes. Some subsequent investigators, not visiting any typically meta-sedimentary section, concluded that the Vishnu schist was of igneous origin. For many years the pre-Algonkian rocks of the Inner Gorge were regarded as an insoluble igneous complex.

Recognizing the great significance of these old rocks in the elucidation of the early history of the earth, Dr. John C. Merriam, President of the Carnegie Institution, has personally encouraged field studies and research. In the years from 1932 to 1937 detailed work in various parts of the Bright Angel Quadrangle established the principal rock types and relationships. It is pleasing to note that these give full substantiation to the pioneer observations of C. D. Walcott.

In summary, the Archean history of the Grand Canyon region embraces four clearly distinguishable periods: (1) deposition of thick, monotonous sedimentary formations, (2) volcanic eruption, (3) orogeny and granitic intrusion, and (4) subsequent erosion.

1. Sedimentation. A great thickness of sediments was laid down. These were dominantly sandy clays but quartz sands and ferruginous beds were

¹ C. D. Walcott. Pre-Cambrian igneous rocks of the Unkar terrane. U. S. Geol. Surv. 14th Ann. Rept., pt. 2, pp. 497-524 (1894).

also deposited. Some of the members were slightly calcareous but no limestones were formed. Some characteristic sedimentary structures have survived despite subsequent metamorphism. Cross-bedding is common, well-preserved ripple mark has been found, and ellipsoidal calcareous concretions have been observed in what was originally an argillaceous sandstone. It is believed that the sediments accumulated as marine deposits in a shallow, subsiding geosyncline.

2. Volcanism. Near the end of this period of sedimentation volcanism occurred and basaltic lavas and tuffs were erupted. In some of the metamorphic derivatives "pillow structure" is still clearly discernible and probably indicates that these flows were submarine extrusions. A great thickness of basaltic lava accumulated and sedimentation was interrupted, but at intervals throughout this period small amounts of sandy clay were deposited.

3. Orogeny. Great northeast-southwest trending mountain ranges were built. The sediments and lavas were folded and metamorphosed. The sandy shales were converted into quartz-mica schists and the sandstones into quartzites, while the basalts were changed to amphibolites. The more intense stages of metamorphism, represented by such rocks as garnet-sillimanite gneiss, were probably superimposed by contact-metamorphic processes during the period of intrusion.

4. Intrusion. Perhaps concomitant with the declining phases of the orogeny, and very likely continuing after it, came intrusions of granitic magma. These formed the larger bodies of the granite and gave rise to numberless small dikes and to such phenomena as granitization of the meta-sediments, production of migmatites, etc. The last event of the intrusive period is represented by the intrusion of abundant pegmatites, many of which form lit-par-lit structures in the schists. The pegmatites together with the granite are responsible for additional metamorphism of the meta-sediments and lavas.

5. Ep-Archean erosion. During a very long period of erosion almost all the relief of the land was obliterated.

In order to gain a coherent concept of the interrelationships, distribution, and structure of the Archean rocks, it was recognized that an examination of the entire exposed area was necessary. Accordingly a boat expedition down the Colorado River from Lee's Ferry to Pierce's Ferry, Arizona, was undertaken. Three especially constructed river boats were obtained and a competent personnel was assembled. Mr. Frank B. Dodge, who had made numerous trips on the Colorado, was employed as chief boatman and assisted in the general organization. Through his skillful direction of the navigation, mishaps were avoided and the journey was carried out successfully. Owen R. Clark and Merrill F. Spencer, experienced boatmen, were likewise employed and contributed materially to the success of the expedition. In view of the necessity of securing complete geological data on both sides of the river during a rapid one-way traverse it was considered desirable to increase the geological personnel. Therefore, Dr. J. T. Stark of Northwestern University, who had studied the Archean formations of the Rocky Mountains, and Mr. Robert P. Sharp, who had formerly been a graduate assistant at the California Institute, were invited to participate. Mr. E. D. McKee,

Park Naturalist of Grand Canyon National Park, joined the expedition at the foot of the Bass Trail to study Paleozoic stratigraphy during the remainder of the trip. The writers greatly appreciated the cooperation and enthusiasm shown by all members of the expedition, even under trying circumstances.

The program included mapping and collecting during slow descent of the river. Transportation by boats proved highly successful and made accessible large areas of Archean which had never been studied before. Observations on structure and areal geology were made in tributary canyons of the Vishnu, Bright Angel, Shinumo, and Havasu Quadrangles. The topographic "Plan and profile of the Colorado River" prepared by the United States Geological Survey party under Colonel Birdseye in 1923 furnished an accurate and reliable control for detailed work in the Granite Gorges. Supplementing this, and of great value in locating structures and specimens in a precipitous terrane, was a strip of overlapping vertical airplane photographs having a scale of approximately 600 feet to the inch along the river. These covered all of the Granite Gorges and some adjoining Paleozoic and Algonkian sections.

In perhaps few other places in the world can be found a section through Archean terrane so continuously and so excellently exposed. For over 40 miles in the main Granite Gorge, for some tens of miles in the Middle Granite Gorge, and for nearly 50 miles in the Lower Granite Gorge of the Colorado, there is literally continuous outcrop of Archean rocks. Furthermore, because of the scour and polish of the swift, silt-laden waters of the Colorado, outcrops at times exhibit surfaces comparable to those produced by artificial laps, and textures and structures are displayed with surprising clarity. Because of these features, much interesting detail on the intricate processes of igneous invasion and of metamorphic recrystallization was obtained. The porphyroblastic character of the majority of the gneisses in the section is unmistakable; and the replacement origin of much of the granite, as well as of the gneiss, is strongly suggested.

The examination of the entire Archean section confirmed the earlier conclusion that the lithology of the meta-sediments is relatively uniform. No new types were found. The great thickness of sediments varying only from fine-grained, argillaceous sandstones (now quartzites and sericite-quartzites) to sandy shales (now quartz-mica schists) is comparable to some sections of the Belt series in the northern Rocky Mountain Province, where tens of thousands of feet of fine-grained clastic sediments were deposited in late pre-Cambrian time without change to limestone on the one hand or conglomerate on the other. As indicated later, there is some close folding in the schist which renders any estimate of thickness only approximate. A minimum figure is given by the steeply eastward-dipping section between Crystal Creek and Monument Creek, which is approximately 5 miles across the strike and only slightly injected by granite. Clearly exposed massive beds preclude close folding and their non-repetition eliminates the possibility of broad folding, either of which structures would exaggerate the thickness. The schists east from Monument Creek to Bright Angel Creek should doubtless be added, but an estimate of their true thickness is impossible owing to an increased amount of intrusion. Twenty-five thousand feet may therefore

be regarded as a minimum thickness for the meta-sediments, but their true thickness may be twice as much.

For the meta-sedimentary rocks the authors propose the name Vishnu series, a usage which will restrict the term "Vishnu schist," originally proposed by Walcott for the entire Archean terrane. The name is appropriate for two reasons: first, it perpetuates a term proposed by one of the leading students of the pre-Cambrian of the past generation and one which is indelibly associated with the Grand Canyon section; second, the section of Archean rocks exposed in the lower canyon of Vishnu Creek is an excellent type locality, for all variations in character from relatively pure quartzites to highly micaceous schists are present, as well as some of the rather unique concretionary forms which seem to be distinctive of certain horizons of the Vishnu series.

As a result of the river expedition amphibolite is recognized as a rock type of formational importance. Some hundreds of feet were previously known in the vicinity of Clear Creek, where amygdaloidal and ellipsoidal structures were found preserved. Highly injected and granitized amphibolites were known to occur between Cremation Creek and Horn Creek. The expedition found in the Middle Granite Gorge and in isolated exposures in Conquistador Aisle perhaps 4000 feet of amphibolite. Although most of the outcrops show only massive amphibolite, there are some intercalations of thin layers of quartzite and mica schist. The relationships are such as to suggest that the amphibolites were in part basic flows and in part basic tuffs. To this volcanic series a new formation name will be assigned.

The Vishnu series may be correlated with the Pinal schist of central Arizona and with various Archean schists of the Great Basin. Its relationship to the section of the Canadian Shield remains uncertain. There is no compelling evidence of simultaneous Archean volcanic activity in widely separated areas, yet the similarity of rock types and stratigraphic position suggests correlation of the volcanic series with the Keewatin series of the Lake Superior district.

Both the Vishnu series and the volcanics are older than any of the plutonic rocks of the Grand Canyon. Indeed, no evidence was found indicating more than one *major* period of igneous invasion, although there is evidence that certain intrusives may belong to earlier, other to later stages within the major cycle. In few places is there direct evidence of intrusion on a batholithic scale. On the other hand, the suggestion is strong in many places that the present section is cut chiefly along the roof and uppermost portions of a large batholith, or batholiths, where small to moderate-sized and irregularly shaped cupolas are abundantly exposed; where recrystallization, replacement, and pyrometasomatic effects in the adjoining and overlying country rocks have been of most intense degree; and where there has been enormous development of pegmatite.

In contrast to the volcanic rocks, which are entirely of basic type, the plutonic rocks are very largely acidic, ranging from tonalite to granite. To what extent different exposures of somewhat different petrologic character should be separated, or to what extent they should be grouped as cupolas belonging to a single parent batholith, is problematical.

In a broad way three principal intrusive groups may be recognized. The first is the pink to red, microcline-rich, coarse-grained granite previously described as the Zoroaster granite, which occurs in the Bright Angel Quadrangle. The largest single mass is a little over a mile across and lies in and downstream from Zoroaster Canyon. The Zoroaster granite shows similarity to the Algomian and other Archean granites of the Canadian Shield. The second group is that described by L. F. Noble¹ as quartz diorite. This outcrops over a large area in the Shinumo Quadrangle in the Upper Granite Gorge. The third and largest mass is a coarse-grained gray granite outcropping from the beginning of the Lower Granite Gorge to the Grand Wash Cliffs.

Coincident with the emplacement of these plutonic bodies, there was a vast amount of recrystallization (doubtless superposed upon a milder dynamic metamorphism) and metasomatism in the adjoining sediments and volcanics. Metamorphic intensities varied considerably, even within short distances, as evidenced by the presence of garnet-silliminite gneisses close by fine-grained muscovite-biotite phyllites. In some cases there seems to have been actual digestion or replacement of the country rock, and the resulting blend of intrusive and meta-sediment is best considered as a migmatite. Rocks of this kind are well exposed in the vicinity of Phantom Creek, and for this lithologic type (stratigraphically, of course, it represents a mixture of schist and/or amphibolite with granite) we propose the name "Phantom migmatite," thereby designating an accessible type locality and at the same time recognizing the palimpsest and ghost-like features present in this rock!

Pegmatites everywhere represent the last phase of plutonic activity. The enormous development of these bodies is one of the outstanding, as well as one of the most puzzling, features of the Archean in Grand Canyon. For example, for some 25 miles west from Crystal Creek, across the general regional strike, granite pegmatite accounts for from 10 to 50 per cent of the section. Granite, on the other hand, accounts for considerably less of the total section.

Evidence as to the origin of these pegmatites is still inconclusive. The majority clearly fill primary joint cracks in the plutonic rocks, and as clearly exhibit cross-cutting relationships in the schists, when viewed on a large plan. Frequently, too, the spreading of schist folia under the force of igneous intrusion is plain. Viewed in detail, however, conformity with schistosity is often the rule, porphyroblastic development is common, and the evidence for a replacement origin is often compelling. Furthermore, the volume relations are difficult to reconcile with a hypothesis of pure injection. The two phenomena (injection and replacement) are of course by no means incompatible, and it may be that while igneous or aqueoigneous injection accounts for the principal loci, much of the volume of these pegmatite bodies is due to local but extensive replacement.

The paucity of distinctive mineralizers, as evidenced by the rarity of the more unique pegmatite minerals, is worthy of comment. The great bulk of the pegmatites consists of feldspar, quartz, muscovite, and little else. Black

¹ L. F. Noble, U. S. Geol. Surv. Bull. 549, pp. 35-36 (1914).

tourmaline is not uncommon, but is far from being abundant. Garnet is somewhat more common. Beryl, in rare but often well-developed crystals, is found in about half a dozen pegmatites in the entire section. Of other minerals so frequently reported from pegmatites, no trace was found. Possibly this is further evidence favoring the idea of acrobatholithic structure, in that the rarer and more volatile constituents might not deposit close to the parent batholith. And if deposited farther away in the country rock, they have been removed during ep-Archean erosion.

The orogeny following the deposition of the sediments and the extrusion of the volcanics was of great magnitude and is probably to be correlated with the Algonian revolution, now recognized as the most important in deforming the Archean formations of the Canadian Shield. The stress was applied in a southeast-northwest direction producing several broad folds of isoclinal nature and numerous smaller folds. In some localities the small folds may be recognized only by the intersection of flow cleavage with stratification, elsewhere by relationships of drag folds and fracture cleavage on the fold flanks. Excepting in the small folds, flow cleavage is parallel to the stratification. The occurrence of bands of biotite oblique to the schistosity and stratification was first noted by this expedition on Vishnu Creek and was interpreted as representing fracture cleavage. Subsequently this feature was found to check in attitude with that required for development in conjunction with drag folds on fold flanks. In Walthenberg Canyon similar fracture cleavage bands were found cutting across a small fold wherein the flow cleavage was parallel to the fold surfaces, thereby recording two periods of deformation somewhat separated in time. The granitic rocks are believed to have been intruded late in the epoch of orogeny. Much of their foliation is a relict of the assimilated schists.

Archean faulting was recognized at several localities by offset pegmatite dikes where the fault plane was later intruded. Many faults in the Archean were mapped and in some instances it was possible to demonstrate that the movement occurred in pre-Algonkian time. Throughout the Grand Canyon evidence was obtained that later and often recurrent faulting has been dependent on Archean and Algonkian blocks.

The Carnegie Institution Grand Canyon Expedition was very successful in gaining new information on the Archean geology of northern Arizona and in clarifying points previously in doubt. There remain, however, certain unsolved problems on which future work should throw light. For example: no basement, on which the Archean sediments were deposited, has as yet been found. Correlation with other pre-Cambrian occurrences throughout the Southwest is not yet definite; but the subdivision of the Grand Canyon section into distinct formations by this expedition is an important first step in making such correlations possible. A reconstruction of Archean palaeogeography would not only be of local significance, but would have broader geophysical and historical importance. The relationships between the Archean batholiths of the Grand Canyon and those of the Basin Ranges are not yet fully understood. For the immediate future it is hoped that by extending field work in the vicinity of Lake Mead some contribution to these problems may be made.

PHYSICS

Committee on Coordination of Cosmic-Ray Investigations. *Progress report for the period July 1937 to June 1938.* (For previous reports see Year Books Nos. 32-36.)

Instruments. The Institution's precision cosmic-ray meters were continued at the following stations: Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, George Hartnell in charge; Huancayo (Peru) Magnetic Observatory of the Institution's Department of Terrestrial Magnetism, meter C-2, F. T. Davies in charge; National Astronomical Observatory of Mexico at Teoloyucan, D. F., meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research of New Zealand, meter C-5, J. W. Beagley in charge.

The installation of meter C-6, to complete the network of five stations as originally planned by the Committee, was made at Godhavn, Greenland. Before shipment the meter was improved by Dr. Compton and his assistants to permit exposure to cold weather without damage as shown by outdoor tests to 0° C and in the laboratory to considerably lower temperatures. Detailed arrangements on behalf of the Committee were made by Dr. Fleming with Dr. la Cour for the installation. Dr. la Cour designed the special-type building suited to the climate at Godhavn. This design was completed in May and building materials and the cosmic-ray meter, with 1200 kg of 3-mm lead shot purchased in Norway, were shipped from Copenhagen June 4, the meter having been forwarded directly from Chicago to Copenhagen in May. Batteries and recording paper sufficient for a year's operation were furnished because supplies may be forwarded only in the summer. Expenses of shipment, building, and shot were paid by the Committee. The Danish government, besides providing transportation to Greenland, and travel and living expenses of Mr. V. Laursen of Dr. la Cour's staff for five months, generously made a credit of 11,000 Kr. (about \$2500) for expenses including insurance, assistants, heat, and supplies at the Observatory. On October 12, 1938, a cablegram from Dr. la Cour stated the meter was then in operation. The addition of this station, which completes the network proposed by the Committee, will furnish additional data for study and interpretation, valuable particularly as Godhavn is in such high latitude (69° 15' north) and is relatively quite close to the geomagnetic pole.

Dr. R. D. Bennett at Massachusetts Institute of Technology continued experimentation and improvement of meter C-3. Plans were made for its installation late in 1938, in connection with high-altitude studies, at Climax, Colorado (12,000 feet above sea-level); this point on Mount Evans was selected instead of the summit (14,000 feet) because it is accessible throughout the year. This station will be under the supervision of Dr. J. C. Stearns of the University of Denver. Dr. Bennett at the Massachusetts Institute of Technology, Dr. Jesse at the University of Chicago, and Mr. Forbush at the Department of Terrestrial Magnetism have made improvements to reduce considerably the current required for operation. This will reduce the cost of replacements of batteries. Heretofore the National Carbon Com-

pany has generously contributed batteries—a contribution the Committee wishes again to acknowledge gratefully.

Meter C-0 under the direction of Dr. Compton continued in use on cruises in the Southern Pacific Ocean during the year. During the next year he plans to operate this meter on vessels cruising between Seattle, Washington, and Alaska.

The Institution's three Millikan-Neher cosmic-ray meters were continued in operation at the Kensington (Maryland) station of the Department of Terrestrial Magnetism for comparison with the precision-meter records at Cheltenham, for studies of the comparative behavior of the two types of instruments, and for determination of barometric and thermal coefficients.

Because of unsatisfactory performance of batteries of European manufacture the records with Steinke cosmic-ray apparatus at the University of Cape Town were defective. However, P. Gaskell, in charge under the supervision of Professor R. M. James of the Department of Physics of the University of Cape Town, succeeded in making from several unserviceable sets of batteries live sets so that good records were again obtained from June 17, 1938. New batteries were ordered from Europe.

Instrumental technique for determination of the cosmic radiation in the upper atmosphere was further developed by Drs. Millikan, Johnson, and Korff, as indicated in their reports which follow.

Investigations. Forbush's work last year on the relationship between disturbances of the cosmic radiation and of the Earth's magnetism stimulated wide interest; evidence of this appears in coordination of effort indicated by reports of Messrs. Beagley, Forbush, Johnson, and Korff, which follow. The large variation in magnitude of cosmic-ray effects during different magnetic storms indicates that the current-system responsible for different storms flows at different heights about the Earth.

From July 1 to December 31, 1937, Mr. Forbush of the Department of Terrestrial Magnetism devoted about half of his time to cosmic-ray investigations. Beginning with January 1, 1938, on furlough from the Department, he was paid by the Committee and gave full time to the reduction, discussion, and interpretation of cosmic-ray records obtained at the Committee's four stations with the assistance of W. R. Maltby (from December 20, 1937). He completed the discussion begun by Korff of the comparison of the Millikan-Neher and Compton-Bennett meters. He also determined their barometric and thermal coefficients. He discussed statistically solar, sidereal, and annual variations, and bursts of cosmic radiation. An outstanding result during the year based on the records obtained at Cheltenham, Teoloyucan, Huancayo, and Christchurch is Mr. Forbush's discovery of positive evidence of worldwide changes in cosmic-ray intensity which are quite similar at all stations, as indicated in his report below.

In the study of cosmic-ray intensity at high elevations Dr. Johnson spent some time in Minnesota and Canada. At Swarthmore in collaboration with Dr. Korff he further developed single-counter measurements of cosmic-ray observations at high elevations. The technique was greatly enhanced by the development of a radio barograph suitable for balloon flights. As indi-

cated in Dr. Johnson's report, he has further improved the coincident-counter recording of cosmic-ray intensity. The further analysis of geomagnetic cosmic-ray effects shows the field of cosmic-ray measurements at sea-level to be produced by primary radiations, approximately 100 per cent positive.

In Dr. Korff's report is to be noted particularly the cooperation with the National Bureau of Standards and the resulting improvement effected in instrumental appurtenances for high-altitude observations. He has given further attention to the study of the longitude-effect from the counter observations made on flights in Peru and found it to be about 25 per cent at the point of maximum cosmic-ray intensity in the stratosphere as compared with about 4 per cent at sea-level as found by Dr. Millikan.

Dr. Millikan and his associates at the California Institute of Technology made substantial contributions in cosmic-ray investigations including studies (1) on the total cosmic-ray energy entering the atmosphere at different latitudes, (2) on the discovery by cloud-chamber technique of penetrating charged particles of intermediate mass between electrons and protons, and (3) on development of a Geiger counter of high resolution for cosmic-ray meter.

Future program. Funds provided by the Carnegie Corporation for the work of the Committee in 1938, as approved by President Merriam, included (1) continuation of program with precision cosmic-ray meters at five stations and of Steinke meter at Cape Town; (2) continuation of high-altitude research to include observations on mountains and by balloons; (3) development of cosmic-ray counter technique; (4) full-time services of S. E. Forbush and W. R. Maltby for interpretative studies of accumulated records between precision meters; and (5) full- and part-time services of assistants for work being done under Dr. Millikan's direction at the California Institute of Technology.

Several memoranda on possible interrelations of cosmic-ray intensity and geomagnetic variations were prepared by personnel of the Department of Terrestrial Magnetism. Members of the Committee had frequent contact and conferences with Drs. R. D. Bennett, A. H. Compton, T. H. Johnson, S. A. Korff, and R. A. Millikan, research associates of the Institution, and other investigators mentioned above and in the reports which follow. These and previous reports evidence good progress towards resolution of the complexities of cosmic radiation.

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Beagley, J. W., Christchurch Magnetic Observatory, Christchurch, New Zealand. *Cosmic-ray investigations.*

Maintenance. Cosmic-ray meter C-5 was operated throughout the past report year with only minor interruptions. These were due chiefly to the necessity of adding argon to the bomb to maintain the pressure approximately constant.

Reduction of data. Hourly scalings of all cosmic-ray records were kept current. These include departures from balance, bursts, barometric pressure, and temperatures both outside and inside the observing room.

Cosmic radiation and magnetic variations. Following the discovery by Forbush of changes in the intensity of cosmic radiation occurring simultaneously with changes in magnetic horizontal intensity during the magnetic storm of April 24, 1937, the records during succeeding magnetic storms were closely examined for confirmation of this magnetic-storm effect.

This was forthcoming during the intense magnetic disturbance which occurred during January 17-26, 1938, when simultaneous decreases of cosmic-ray intensity were recorded. These decreases varied from 3.7 per cent to 5.4 per cent at different periods of the storm.

A preliminary investigation to determine whether such an effect is associated with minor magnetic disturbances was made. In the particular storms selected the decreases of cosmic-ray intensity were small and of the same order as the variability in the daily means, so too much weight cannot be attached to them. As the disturbances were only of short duration and the decreases in magnetic horizontal intensity were not very great, it is probable that the magnetic moments of the storm-current systems may have been too small to alter the cosmic-ray intensity appreciably.

Seasonal effect. Preliminary investigation of one year's results from the cosmic-ray meter at Christchurch seems to indicate a seasonal variation. Its amplitude is approximately 1 per cent of the total intensity, with a maximum in winter (July).

Azimuthal asymmetry observations. D. M. Hall, of the Observatory's staff, conducted observations on the asymmetry of the cosmic radiation at Christchurch. For this purpose a set of Geiger counters with circuit after Barasch was used. The following conclusions were drawn:

1. An asymmetry in cosmic radiation extends as far south as geomagnetic latitude 48° .
2. The asymmetry is at a maximum at an angle of 30° from the zenith.
3. The magnitude of the asymmetry at this angle is approximately 2 per cent and is of the same order as that obtained in the corresponding latitude in the Northern Hemisphere.
4. The latitude-effect should extend farther south than Christchurch.
5. Positive primary rays are not wholly responsible for the asymmetry.

Mr. Hall intends to extend his observations further in this field and is also endeavoring to arrange his apparatus to obtain continuous records of the vertical cosmic-ray intensity.

Forbush, S. E., Department of Terrestrial Magnetism, Washington, District of Columbia. *Statistical investigations of cosmic-ray variations.* (For previous report see Year Book No. 36.)

Reduction of data. All scalings, with adequate checks, of records obtained with Compton-Bennett meters from Cheltenham (C-1) and Huan-cayo (C-2) were kept current. This includes scalings of departures from balance, of bursts, and of barometric pressure. In addition, several months'

records from two Millikan-Neher electrosopes at Kensington, Maryland, which had been maintained at constant temperature from March to May 1938, were carefully scaled to provide information concerning the temperature-coefficient of meter C-1 at Cheltenham. Daily means of cosmic-ray intensity, corrected for barometric pressure, were kept current for Cheltenham and Huancayo.

The daily mean values of cosmic-ray intensity from April 1936 to December 1937 at Christchurch, New Zealand, were reduced to constant barometric pressure. This reduction was considerably hampered by escape of argon from the bomb of meter C-5.

Reduction of several weeks of cosmic-ray records, which were obtained at Massachusetts Institute of Technology and loaned to us by Professor R. D. Bennett, proved particularly useful in the study of magnetic-storm effects.

The investigation of the magnetic-storm effect on cosmic-ray intensity involved the scaling and checking of some 60 days of magnetograms at the United States Coast and Geodetic Survey.

Intercomparison of instruments. Because of its important bearing upon the temperature-coefficient of Compton-Bennett meter C-1 at Cheltenham, a thorough study was made of a preliminary report by Dr. Korff upon the results of the intercomparisons of Millikan-Neher and Compton-Bennett meters. It was found that the technique used in scaling the Millikan-Neher records was not sufficiently reliable to insure satisfactory data. Using a newly-purchased Argus projector for 35-mm film, a reliable technique was devised for scaling the Millikan-Neher records.

Daily means of cosmic-ray intensity from Compton-Bennett meter C-1 at Cheltenham were compared with daily means for 51 and 132 days, respectively, from Millikan-Neher meters 0 and 1. Over each of these intervals the maximum change in cosmic-ray intensity was about 6 per cent, owing to barometric and other causes. Statistical analyses showed that the relation between the percentage-changes in daily means, over the respective periods, given by the two types of instruments was 1.00 ± 0.04 . In addition, it was found that the variance (square of standard deviation) in the measured daily means for the Millikan-Neher meters was about four times that for the Compton-Bennett meter. This result will be useful in determining the relative merits of the two types of instruments for special investigations.

Temperature-coefficient of Compton-Bennett meter C-1 at Cheltenham, Maryland. Daily means from two Millikan-Neher electrosopes at constant temperature were compared with those obtained from Compton-Bennett meter C-1 at Cheltenham when the temperature of the latter was varied about 15° C. Statistical analysis showed that the differences between the daily means obtained from the two types of meters did not depend upon the temperature of the Compton-Bennett meter C-1. Thus it is quite certain that meter C-1 at Cheltenham has a negligible temperature-coefficient. It is now also certain that the large annual variation (range 3 per cent) in cosmic-ray intensity at Cheltenham cannot be ascribed to an annual variation in the temperature of the meter.

Following this phase of the investigation the temperature of the Millikan-Neher meters at Kensington was varied over a range of about 10° C. Analysis showed that the results from Millikan-Neher meter 1 were also not affected by temperature. Owing to mechanical difficulties which developed in the charging mechanism inside the ionization-chamber of Millikan-Neher meter 0, it was not possible to determine whether that instrument was affected by temperature.

Results from Millikan-Neher meter 1 at Kensington were compared with those from Compton-Bennett meter C-1 at Cheltenham for several periods of a month or more at intervals with a maximum separation of 16 months. The results showed that the differences between the two instruments remained constant within about 0.2 per cent of the total cosmic-ray intensity. This makes it certain that the annual variation in cosmic-ray intensity indicated by meter C-1 at Cheltenham would also be indicated by Millikan-Neher meter 1 at Kensington.

Barometric coefficients. Statistical analyses were made to determine the barometric coefficient and its reliability, separately, from daily means for each of the 22 months' data available for Christchurch. The results proved useful in checking the reduction of the observed values of cosmic-ray intensity to constant pressure of argon. The coefficient for Christchurch was found to be significantly different from that which had been obtained at Cheltenham for meter C-1 when used with bomb 3.

Thus it was necessary to redetermine the barometric coefficient from the results at Cheltenham following the replacement, in March 1937, of bomb 3 by bomb 1 in meter C-1. Statistical analyses were accordingly made to determine the coefficient and its reliability for each of 15 months' data at Cheltenham. These results were in excellent accord with those obtained from Christchurch, for which the altitude and geomagnetic latitude are practically the same as for Cheltenham. Thus an important check was furnished on the effective sensitivity of the two meters, which is essential to an adequate comparison of changes in intensity due to other causes. The cause for the discrepancy between the coefficients obtained at Cheltenham from meter C-1 using bombs 3 and 1 is probably connected with the fact that the first of these bombs had a definitely anomalous saturation-characteristic and also an anomalous temperature-coefficient.

Solar diurnal variation. Analysis has been made of the solar diurnal variation of cosmic-ray intensity at Huancayo, Peru, from data covering some 15 months. The solar diurnal variation at Huancayo agrees approximately in phase and amplitude with that found for Cheltenham, Maryland. These results should provide an important test of the theory, advanced by M. S. Vallarta, that the solar diurnal variation is due to the Sun's magnetic moment. Some progress was made in statistical tests of other possible causes for the solar diurnal variation.

Sidereal diurnal variation. An analysis of data for 595 days at Cheltenham indicated that the apparent 24-hour sidereal wave in cosmic-ray intensity at this station cannot be regarded as statistically significant. Analysis of data for 396 days from Huancayo, Peru, indicates an apparent sidereal wave, the statistical significance of which has not been tested, which is not

in agreement with that for Cheltenham or with that predicted from the theory of Compton and Getting.

Bursts. A preliminary investigation was made of the dependence of the frequency of bursts upon size, based on data for 500 days each at Cheltenham and at Huancayo. It is found that bursts of a given size occur from 2.5 to 3.2 times more frequently at Huancayo than at Cheltenham. The decrease of burst-frequency with size is nearly the same for both stations.

Annual variation. Having eliminated the possibility that the large annual variation of cosmic-ray intensity (range about 3 per cent) at Cheltenham, Maryland, might be due to an annual variation of instrument-temperature, progress is being made toward a comparison of the annual variation there with that from Huancayo, Peru, and that from Christchurch, New Zealand. The results obtained from the analysis of the annual variation will provide further check upon the theory that this may be caused by the magnetic moment of the Sun.

Magnetic-storm effects on cosmic-ray intensity. Most important to theories of magnetic storms are the results of observations on the effects on cosmic-ray intensity associated with magnetic storms. It is now definitely established that worldwide changes of several per cent in cosmic-ray intensity, which were first discovered at the Department of Terrestrial Magnetism, occur during some magnetic storms. Equally definite is the evidence that magnetic storms of equal intensity at the Earth's surface occur without appreciable effects on cosmic-ray intensity. It is found that the ratio of changes in cosmic-ray intensity to those in horizontal magnetic intensity is quite constant during an individual magnetic storm. This is an indication that one and the same current-system is responsible for the changes in horizontal magnetic intensity and those in cosmic-ray intensity. The large variation in the magnitude of cosmic-ray effects during different magnetic storms indicates that the current-system responsible for the different storms flows at different heights above the Earth. It appears improbable that the current-systems of storms with and without cosmic-ray effects both flow within the Earth's atmosphere.

Assuming the current-system for the storm-time field for the two types of storms to consist of a ring concentric with the Earth in the geomagnetic equatorial plane, magnetic data from several observatories were analyzed to determine whether the radius of the assumed ring is, as would be expected, greater for magnetic storms which affect cosmic-ray intensity.

Although the analysis is not conclusive on this point, the results satisfy a necessary condition for the existence of such a ring-current. The occurrence of aurora in temperate latitudes during most of the magnetic storms which affected cosmic-ray intensity is interpreted, after Störmer, to indicate the existence of such ring-currents. The percentage-changes in cosmic-ray intensity during magnetic storms is, within the observational uncertainty, the same at geomagnetic latitudes $50^{\circ}1$ north and $0^{\circ}6$ south. The significant correlation between changes in daily means of cosmic-ray intensity for two stations separated 50° in latitude probably results from the same mechanism responsible for the magnetic-storm effects.

On worldwide changes in cosmic-ray intensity. Based on cosmic-ray results from Cheltenham, Teoloyucan, Huancayo, and Christchurch, it is found that the data indicate that:

1. At Huancayo there is no 12-month wave of appreciable amplitude.
2. At Cheltenham there is a 12-month wave, maximum in January, with amplitude about 1.6 per cent of the total cosmic-ray intensity.
3. At Teoloyucan there is a 12-month wave, maximum in January, with amplitude about 1.0 per cent of the total cosmic-ray intensity.
4. At Christchurch there is a 12-month wave, maximum in July, with amplitude about 0.8 per cent of the total intensity.
5. There is a high correlation between the monthly means at any two stations after removing the 12-month waves.
6. There is a high correlation between the means for each one-third of a month at any two stations after removing the 12-month waves.

The indications (5) and (6) give positive evidence of worldwide changes in cosmic-ray intensity which are quite similar at all stations. In addition to these worldwide changes, there exist 12-month waves in the data which have opposite phases in the two hemispheres. It seems impossible to interpret the 12-month waves in such a way as could be explained by the hypothesis of a solar magnetic field proposed by M. S. Vallarta, since he concludes that this should give rise to an annual variation with maximum in northern summer.

Statistical analyses of the worldwide changes give consistent evidence that, when expressed in percentage of the absolute cosmic-ray intensity at each station:

1. The worldwide changes at Cheltenham and Christchurch are each between about 5 and 10 per cent greater than at Huancayo.
2. The worldwide changes at Teoloyucan are approximately 50 per cent greater than at Huancayo or at Cheltenham.

The difference in altitude between Huancayo and Christchurch and between Huancayo and Cheltenham introduces uncertainty concerning a possible latitude-effect at sea-level in the worldwide changes in cosmic-ray intensity. If the absolute values of cosmic-ray intensity at Teoloyucan and Huancayo are accepted, then, since the elevations of these two stations are not greatly different, the fact that the worldwide changes at Teoloyucan are about 50 per cent greater than for Huancayo would have to be ascribed to difference in latitude. Also the difference between Teoloyucan and Cheltenham would have to be ascribed to difference in elevation. Results from a high-altitude station such as Mount Evans not only would be useful concerning this point, but would indicate also whether the amplitude of the 12-month wave depended upon elevation.

In any case the present investigation shows that the worldwide effect in cosmic-ray intensity can be compared at different stations with a reliability which is probably at least as great as the reliability with which the absolute values of cosmic-ray intensity at different stations are known.

Finally, it should be pointed out that the effects here discussed could not have been found unless all the meters involved had remained remarkably

stable. Thus the worldwide effects in cosmic-ray intensity provided indirectly a test upon the stability of instruments at the different stations.

While worldwide effects in cosmic-ray intensity were previously known to exist during some magnetic storms, it was not anticipated that there were changes in cosmic-ray intensity over long periods which, as shown in this investigation, are also worldwide in character. That these worldwide changes appear roughly to decrease with increasing magnetic activity suggests that the mechanism responsible for them is similar to that for the magnetic-storm effect.

Messrs. George Hartnell, J. W. Beagley, and F. T. Davies of the Cheltenham, Christchurch, and Huancayo observatories, respectively, have had charge of the meters, the records from which have supplied the data for the above discussions. From July to December 1937 the writer, as one of the staff of the Department of Terrestrial Magnetism, gave part-time service to the reductions; from January 1938, while on temporary furlough from the Department of Terrestrial Magnetism, he devoted full-time service to this work. Since December 20, 1937, he has been fortunate in having the assistance of W. R. Maltby.

Johnson, Thomas H., Bartol Research Foundation, Swarthmore, Pennsylvania. *Studies of cosmic rays.* (For previous reports see Year Books Nos. 32-36.)

The cosmic-ray intensity at high elevations in northern latitudes. The radio balloon technique developed with support of the Carnegie Institution during the previous year has been used for studies of the low-energy end of the cosmic-ray spectrum. Flights were made in Swarthmore, Pennsylvania, where the minimum energy for vertically entrant cosmic rays is 3.5 bv (billion volts), in northern Minnesota where the minimum energy is 2 bv, and in Churchill, Manitoba, where the minimum energy is 1 bv. Any differences in the intensities at these stations can be attributed to the cosmic radiation in the energy-interval between the respective low-energy limits. Satisfactory data were obtained at the two northern stations for all depths in the atmosphere greater than 2 meters of equivalent water and for somewhat lesser depths at Swarthmore. Within the experimental uncertainties, estimated as of the order of 5 per cent, the intensities were the same at all three stations. This finding is also in agreement with the results of Carmichael and Dymond, and of Bowen, Millikan, and Neher, whose experiments have been reported since the conclusion of these studies.

An analysis of all the high-elevation experiments in northern latitudes shows that it is not possible to conclude that there are fewer cosmic rays in the low-energy region of the spectrum than in the higher-energy regions. Because of the low energy contributed by each ray there could be a larger number of rays in this region without there being any detectable contribution to the measured intensity even at the highest attainable elevations. The multiplication of secondaries plays such an important rôle in the first layers of the atmosphere that the intensity which one measures is more closely proportional to the incident energy than to the number of primary rays. The

results are consistent with a distribution in which the number of rays can be represented by an exponential function of the energy.

Single counter measurements of the cosmic radiation at high elevations. In collaboration with Dr. S. A. Korff, radio balloon flights have been made in Swarthmore in which single counters have been used for the measurement of the cosmic-ray intensity. In this work we have attempted to achieve the same statistical accuracy as has been realized in the electroscope-measurements of Bowen, Millikan, and Neher. Large-sized counters, discharging several thousand times a minute, have been used in conjunction with a simple scaling circuit to reduce the actual count by an adjustable factor for convenience in transmitting and recording the signals. A measurement of the intensity accurate to about 1 per cent can be made in one minute with this technique. One of these flights was adjusted to level off at the ceiling, which happened to be 66,000 feet, and the instrument continued to record and transmit the intensity at this elevation for a period of eight hours. Another of these flights went to 80,000 feet.

Although these investigations have not been carried far enough to yield publishable results, some preliminary data have been obtained which bear upon the following problems: (a) the diurnal variation of the cosmic-ray intensity at the top of the atmosphere and possible solar contributions to the soft component of the cosmic radiation; (b) the effect of magnetic storms upon the cosmic radiation at the top of the atmosphere; and (c) the possible existence of X-rays or gamma-rays in the high atmosphere emanating from the Sun during solar eruptions, and an attempt to find by Geiger counter technique the radiations which produce the radio fade-outs.

Development of a radio barograph suitable for cosmic-ray studies. An aneroid barograph free from hysteresis and back-lash has been devised which uses the Olland-Curtiss principle. A nonlinear scale gives greater sensitivity at low pressures and the instrument is accurate to within about 1 mm at the low-pressure end and to within about 3 mm at the high-pressure end.

Development of technique for projected coincidence counter studies of the directional distribution of the cosmic radiation at high elevations. A technique for the control of the orientation of the balloon apparatus has been developed. With our leveling-off technique we are now in a position to carry on the measurements of the directional distribution of cosmic rays at high elevations. This work is projected for the near future.

Continuous coincidence counter recording of the cosmic-ray intensity. The apparatus used in previous years for automatic shipboard recording of the cosmic-ray intensity has been operated for most of the past year in Swarthmore. The large fluctuations found in high latitudes during the shipboard recordings have been confirmed and an attempt has been made to correlate these with the absolute humidity. Two sets of data comprising 70 days and 51 days respectively have been subjected to a least squares analysis in which barometric and humidity coefficients were evaluated simultaneously. Large humidity coefficients were found in the sense that high humidity correlates with a low cosmic-ray intensity, but the correlation is not a close one as in the case of the barometer-effect.

Further analysis of the geomagnetic cosmic-ray effects. The positive-negative composition of the primary cosmic radiation has been determined by a new type of analysis from the asymmetry measurements of the 1933-1934 surveys and from Compton and Turner's recent measurements of the sea-level latitude-effect. The measurements of Compton, of Hoerlin, and of the writer on the variation with elevation of the geomagnetic effects have been used in converting the electroscope data of the latitude-effect to correspond to the intensities of vertically entrant radiation. The result of the new analysis shows, with a greater accuracy than was realized in former attempts, that the field sensitive cosmic rays at sea-level are produced by a primary radiation which is practically 100 per cent positive. The experimental accuracy will not permit a negative component exceeding 10 per cent of the total field sensitive radiation. Experiments of the 1934 survey, as well as similar experiments by Korff and Rossi in which lead shields were used during the measurement of the asymmetry, can now be interpreted in the light of our present knowledge of the hard and soft components of the cosmic radiation, as indicating that the asymmetry is a property of the penetrating component. The soft component which constitutes a large part of the cosmic radiation at high elevations may be equally positive and negative.

Our present knowledge of the primary cosmic radiation may be summarized as follows: (1) The hard component primaries are entirely positive (asymmetry and latitude-effect analyzed by Lemaitre and Vallarta theory). (2) The soft component primaries are electronic (intensity-depth curve at high elevations consistent with the theory of electron multiplication), and these rays are probably equally positive and negative (necessity of a neutral condition in intergalactic space and evidence for complete symmetry of shower-particles on mountain tops). (3) The gamma radiation is far too faint in comparison with the electron component to represent an equilibrium between cosmic rays and matter (latitude-effect of cosmic rays at high elevations). (4) The positive hard component primaries must be accompanied in intergalactic space by negatives of equal velocities and of equal space density (to preserve a neutral intergalactic space). The absence of these negatives in the sea-level radiation can be easily accounted for by supposing that the negatives are electrons while the positives are protons. The heavier positives will carry most of the energy (since the velocities are equal) and will pass readily through the Earth's field, whereas the negatives will be deflected. Within the atmosphere these primary protons produce the secondary penetrating component, consisting of heavy electrons and possibly neutrons.

Personnel. The experiments in Minnesota and Manitoba were made with the help of John Marshall, Jr. A. A. McKenzie helped with the preparation of the instruments. The Minnesota Department of Conservation through the courtesy of G. M. Conzet supplied facilities and additional personnel for the Minnesota experiments, and J. Patterson of the Canadian Meteorological Service arranged for the Churchill experiments. Dr. S. A. Korff and Roy W. Prince have cooperated in the recent work in Swarthmore. Miss Carol Lipman has helped with the reduction of data.

Korff, S. A., Department of Terrestrial Magnetism, Washington, District of Columbia, and Bartol Research Foundation, Swarthmore, Pennsylvania. *Cosmic-ray investigations*. (For previous report see Year Book No. 36.)

The investigations made during the year 1937-1938, with the aid of funds allotted by the Carnegie Corporation through the Carnegie Institution of Washington, may be divided into two parts: (a) a long-range program for the comparison of identical and different meters over long periods; (b) the study of cosmic radiation at high elevations, the data being automatically transmitted from free balloons by short-wave radio.

Program of meter-comparison. Records obtained at the Huancayo Magnetic Observatory, at a station occupied at Tielio, Peru (elevation above sea-level 15,600 feet), and at the Kensington, Maryland, laboratory of the Department of Terrestrial Magnetism have been measured and bursts in the intensity of cosmic radiation have been classified and compared. The bursts were studied to ascertain whether there was any variation of frequency of occurrence, or of energy-distribution, with latitude. The primary cosmic rays are more energetic, on the average, in the equatorial zone, where rays below 15×10^9 electron-volts are excluded by the Earth's magnetic field, and hence some latitude-effect in the bursts might have been anticipated. The bursts were found to have the same distribution-in-energy at all stations. The frequency of occurrence of bursts at Huancayo is not essentially different from that found by other observers at similar elevations in northern latitudes. The bursts were found to increase with elevation at a rate much faster than the total radiation. This is in accord with the view that bursts and showers constitute one of the chief mechanisms through which cosmic rays lose energy as they pass through the atmosphere. The observations further indicate that the bursts are produced by the "soft" component of the radiation, of which only a small fraction reaches sea-level.

The operation of the three Millikan-Neher meters of the Carnegie Institution of Washington at the Kensington Radio Laboratory of the Department of Terrestrial Magnetism was continued during most of the past report-year by Forbush. Records are now available for about one year from each instrument. Maintaining two of the Millikan-Neher instruments at constant temperature for about three months, while the temperature of the Compton-Bennett meter C-1 at Cheltenham was varied, enabled Forbush to show that the temperature-coefficient of meter C-1 is, within the small statistical uncertainty, zero. Similarly, no effect of temperature on Millikan-Neher meter 1 was found. Results from Millikan-Neher meter 1 and from Compton-Bennett meter C-1 for three periods of several weeks, separated by as much as one year, have been analyzed by Forbush and indicate excellent agreement between the two instruments.

Radio-transmitted balloon observations. Two programs have been carried out, continuing the observations of cosmic-ray intensities in the stratosphere and the transmission of the data by radio from free balloons.

Flights in cooperation with the National Bureau of Standards. The project of cooperation with the National Bureau of Standards was carried to completion, and a series of flights was made at Washington. In some of these flights, altitudes of over 100,000 feet were attained. The cosmic-ray intensities observed in these flights indicated (a) that a satisfactory agreement may be obtained between counter- and electroscopes-measurements in the stratosphere and (b) that the intensity at high elevations is considerably lower than it is at about 60,000 feet. This latter effect further serves to emphasize the conclusion previously drawn that the bulk of ionization measured in the upper atmosphere is produced by secondaries. The rapid increase in the production of secondaries as the primaries penetrate the first 5 per cent of the Earth's atmosphere gives support to the Carlson-Oppenheimer theory of energy-loss through the production of multiplicative showers.

A flight was also made at Balboa, Canal Zone—the first to be made under tropical conditions. This opportunity to test the effects of excessive humidity and heavy static upon the equipment has proved useful in suggesting the precautionary measures necessary in further tropical flights.

Longitude-effect. The longitude-effect was computed from counter-flight observations made in Peru, as compared with flights made by Millikan and his collaborators with electroscopes in India. This effect, reported by Millikan as about 4 per cent at sea-level, was found to be about 25 per cent at the point of maximum cosmic-ray intensity in the stratosphere. This value is in good agreement with the figure calculated by T. H. Johnson from an analysis of the energy-distribution of the primary rays.

Cooperation with Dr. T. H. Johnson. A project for making flights in cooperation with T. H. Johnson was undertaken. A summary of the results of this work is also given in the report by T. H. Johnson. The purpose of this program was (a) to develop the single counter as an instrument for measuring cosmic radiation, comparable in accuracy with an electroscopes, and (b) to use the counter so developed for a series of measurements. To accomplish this purpose, further development work was done during January, February, and March 1938 on the technique, and the accuracy obtainable both in pressure and in cosmic-ray intensity measurement was considerably improved.

Receiver technique. A new amplifier was designed and built, which enabled an ordinary commercial receiver to be used for this work. The new arrangement is particularly free from undesirable effects due to electrical noise and static, and hence permits reception under conditions hitherto impossible. A new tape-register was also built, giving a record which can be read with greater accuracy and ease.

Barograph. The barograph-system used in previous flights in Washington and Peru was further improved, both in accuracy and in reliability. Careful tests were made for reproducibility of results and for constancy of characteristics over periods of time.

Cosmic-ray meter. The new circuit described in the report of T. H. Johnson was adapted to the transmission of scaled impulses from a large

single counter, yielding an accuracy considerably greater than that previously attained.

Flights at Swarthmore. A series of eight flights was made at Swarthmore, Pennsylvania, using the improved technique, during April, May, and June 1938. Altitudes up to 80,000 feet were attained, and one flight remained at 66,000 feet for eight hours. The results have yielded measurements of cosmic-ray intensity up to within 2 per cent of the top of the atmosphere, with an accuracy hitherto attainable only with electroscopes. The results show a rapid increase in the intensity of the cosmic radiation between altitudes of 25,000 and 60,000 feet, and that the ionization reaches a maximum at a little above the latter elevation. The measurements of the rate of increase are in good agreement with those reported by Millikan using electroscopes. One of these flights was made during the latter portion of a severe magnetic storm. The results showed that, as the magnetic field-strength was returning to normal, no measurable effect was observed in the cosmic radiation. The development of the technique has been carried to the point where flights may be made as a matter of routine.

Cooperation. It is a pleasure to acknowledge cooperation received from the National Bureau of Standards and from Dr. T. H. Johnson in connection with the cooperative programs described above. Advisory assistance regarding balloon technique was received from the United States Weather Bureau. To the Peruvian government, and especially to Dr. G. A. Wagner, Director of the Peruvian Meteorological Service, are due thanks for assistance of the utmost value with the observations made in that country. For assistance in Panama the author is indebted to Dr. J. Zetek. Helpful assistance with various phases of the work has been received from J. A. Fleming, W. F. G. Swann, S. E. Forbush, and many others. Acknowledgment is also made to the Commander of the U. S. S. *Icarus*, to Dr. E. A. Abbey, and to others who have cooperated in returning to us our instruments recovered from flights, together with complete data regarding the circumstances of finding them.

Millikan, Robert A., California Institute of Technology, Pasadena, California. *Studies of cosmic rays.* (For previous reports see Year Books Nos. 31-36.)

The results obtained between July 1, 1937 and June 30, 1938 in the cosmic-ray studies carried on at the California Institute of Technology with the aid of funds supplied by the Carnegie Corporation of New York administered by the Carnegie Institution of Washington may be very briefly summarized as follows:

Studies of Bowen, Millikan, and Neher on the total cosmic-ray energy entering the atmosphere at six different latitudes as determined by the ionization in electroscopes carried by balloons practically to the top of the atmosphere. 1. The rate at which cosmic-ray electrons of energies between 6.7 billion electron-volts and 17 billion e-volts enter the atmosphere is one such shot every 11 seconds per cm^2 .

2. The total cosmic-ray energy brought to the earth by all entering electrons of energy smaller than 6.7 billion e-volts is but two-thirds of that brought in by the foregoing band of entering electrons.

3. The total cosmic-ray energy brought to the earth by all entering electrons of energy higher than 17 billion e-volts plus that brought in by all photons of all energies is but 8 per cent larger than that brought in by the electron band described in (1).

4. Cosmic-ray electrons then come into the Earth as a limited band of energies, which band has a maximum at from 6 to 7 billion e-volts. This band has the range of energies to be expected if the total mass energy of the atoms of the only abundant elements save hydrogen and helium could be transformed in toto into two oppositely directed cosmic rays. Hydrogen and helium would be largely cut out anyway by the Sun's magnetic field. See (6) below.

5. The smallness of the number of entering photons (see 3 above) requires that the entering rays cannot have come through an appreciable amount of matter in comparison with an atmosphere in traveling from their place of origin to the Earth, and hence that they cannot have originated within the stars or in any portions of the universe in which matter is present in appreciable abundance.

6. Dr. Paul Epstein by a careful analysis of the effects on cosmic-ray electrons of the Sun's magnetic field has shown that if that field at the Sun's surface has a value of 25 gauss, no electrons of less than 1.6 billion e-volts can reach the earth. No additional electrons should therefore be found entering the Earth's atmosphere north of 58° north magnetic latitude, in agreement with the results of the foregoing balloon flights.

7. Cosmic rays can be thus used to set an upper limit to the value of the Sun's magnetic field. Thus the often assumed values of 40 or 50 gauss are now found impossible since no additional electrons could then reach the earth north of Omaha, 51° magnetic latitude, where many are found by Bowen, Millikan, and Neher.

Studies of Carl D. Anderson, Seth Neddermeyer, and assistants by Wilson cloud-chamber techniques on electrons and penetrating charged particles of intermediate mass between electrons and protons appropriately named mesotrons (intermediate particles). By building a cloud-chamber in which one of the two activating tube-counters is inside the chamber it has become possible to catch cosmic-ray particles at the very end of their ranges. With this new apparatus 10,000 cosmic-ray photographs have been taken. One very remarkable photograph shows a "dying cosmic ray," a mesotron which ended its range in the gas itself and which has a range and curvature consistent only with a mass of about 240 electron masses. This furnishes direct, unambiguous photographic proof of the existence of these new particles discovered in a series of Anderson-Neddermeyer researches extending from 1934 to 1937.

Anderson and Neddermeyer are now experimenting with very large cloud-chambers in the hope of increasing largely the resolution in the measurement of mesotron masses, one of the most vital problems of the new nuclear physics.

Neddermeyer has published a theory in which mesotrons are considered to be higher mass states of ordinary electrons, possessing possibly a series of different masses.

Mr. Vargus, assisting Anderson, has measured the angle of scattering in traversing a 1-cm platinum plate of 361 particles of energies above 500,000,000 e-volts and obtained within this range scattering angles agreeing with the Mott-Williams scattering formula. In lower-energy ranges, however, the observed scattering is about one-half the theoretical.

Mr. Boggild has developed a counter to be used inside a chamber for absorption-measurements in a very light element in order to determine (a) what is the mechanism of electron-absorption in addition to pair formation and ionization along the track, (b) what are the relative numbers of electrons and mesotrons to be found in the lower-energy ranges, and (c) whether the mesotron has a unique mass, and whether it is possible to determine its mass more accurately.

Neher and Pickering: development of a Geiger counter of very high resolution for cosmic-ray balloon work. Successful daily flights made over a period of ten months at Burbank, California, using radio meteorographs made at the California Institute of Technology, have resulted in reliable transmitting and receiving equipment which uses a wave-length of but 1.6 m. This wave-length is so short as to be free from the usual local disturbances which have hitherto impeded progress in the receipt of radio meteorograph signals from balloons. Neher and Pickering have adapted these techniques to the problem of sending signals from a pair of vertical Geiger counters carried up by balloons and activated by cosmic rays.

To gain accuracy they have developed Geiger counters of large cross-sectional area (5 by 2.75 inches). These have about ten times the area and will therefore give ten times the counting rate of any counters used heretofore for balloon work. The counters have a time of reaction of less than 10^{-8} sec. It is necessary therefore to use only two counters even of this large diameter for coincidence measurements in order to have a very small number of accidental counts. The efficiency is also 100 per cent to within an accuracy of 1 per cent with a background counting rate of 30,000 per minute. This is approximately the number of background counts to be expected as a maximum on a flight. The data for a flight will therefore need no correction either for loss of efficiency or for accidentals.

The recording mechanism has been successfully worked out so that both the barometer and the signal from the counters are recorded in a permanent form.

The maximum counting rate to be expected from two Geiger counters counting coincidences due to particles coming mainly from a cone of 30° about the vertical is from 800 to 1000 per minute. An average over a period of five minutes will therefore give a probable error of ± 1 per cent. This is comparable with the accuracy attainable with the present balloon electroscopes, and very much higher than in preceding counter measurements.

Preliminary flights are expected to be made within the next few months.

Epstein, P. S., and G. W. Potapenko, California Institute of Technology, Pasadena, California. *Study of influence of the earth curvature on the propagation of short electromagnetic waves.*

The grant made by the Carnegie Corporation of New York and administered by the Carnegie Institution of Washington for study of reception of micro radio waves has been used to determine as accurately as possible the intensity of waves transmitted over various distances. The comparison of the results with the theoretical values will give a measure of the secondary effects omitted in the theory (such as absorption of the atmosphere, etc.).

The two wave lengths of 5 m and 1 m were selected as the most promising. In either case the apparatus was designed to consist of three portable units: (a) the power pack with specially designed stabilizers; (b) the transmitter or oscillator; (c) the receiver or field strength meter. To insure an easy variability of the distances, it is intended to set up the power pack and transmitter on the shore of the Pacific and to mount the field strength meter on a boat.

On June 30 the state of work on the project was as follows:

5-m waves. All three units of the apparatus (including a frequency stabilizer of standing wave type for the transmitter) are completed, tested in the laboratory, and ready for field work.

1-m waves. (a) The power pack is completely built. It contains an elaborate voltage stabilizer of special construction which will be described elsewhere. (b) The transmitter is designed, its parts built, and ready for assembly. (c) The field strength meter is designed but not yet built.

Committee on Study of the Surface Features of the Moon. *Progress report for the period July 1937 to June 1938.* (For previous reports see Year Books Nos. 26-36.)

During the past year the series of measurements by visual methods on the plane polarization of sunlight diffusely reflected by different areas on the moon's surface and by different terrestrial materials has been completed and the report on the work is in preparation. The results indicate clearly that the materials exposed on the moon's surface are of light, porous nature and produce polarization effects similar to those observed in sunlight diffusely reflected by pumice and volcanic ashes high in silica.

Progress has been made with methods other than visual for measuring the percentage amount of polarization in diffusely reflected sunlight. These include: (a) A vacuum thermoelement used with a special Wollaston prism of quartz and with a lens system of fused silica. It has not been possible heretofore to obtain with this method the degree of sensitivity necessary for the purpose. (b) A polarization spectrograph consisting of fused silica optical parts and a Wollaston prism of quartz. The results obtained with this instrument have not been entirely satisfactory and further work with it will be necessary to obtain the desired degree of sensitivity. It should prove to be of greatest value in the ultraviolet and near infrared parts of the spectrum. (c) A photoelectric cell in a direct current circuit similar to that employed by Dr. Joel Stebbins in stellar work and used with a special Wol-

laston prism of quartz. This apparatus is still in the experimental stage; but the results obtained with it are promising. (d) A rotating polarizing prism used together with a photoelectric cell and a special new high-gain alternating current amplifier designed by Dr. Ellis Johnson of the Department of Terrestrial Magnetism, and constructed in its workshop. The maximum sensitivity of this amplifier is attained at a frequency of 10 cycles per second or a rotation period of the polarizing prism of $\frac{1}{6}$ second. The new apparatus has been assembled and preliminary tests indicate that its sensitivity is high; theoretically the apparatus should measure the amount of polarization to 0.1 per cent. The Moon Committee is indebted to the Department of Terrestrial Magnetism for the development of the new amplifier.

In connection with the study of the physiography of the moon's surface it is essential to obtain more information than is at present available on the shapes and relations of its different topographic features. As the result of studies by selenographers during the past three centuries the heights of many of the mountains and the depths of many craters have been measured by several different methods; but each measurement has required tedious computations to derive the desired information. So much labor is needed to obtain results by these methods that several years ago the Moon Committee devised a new method for the purpose; this grazing-incidence method promises to yield valuable information. It is based on a simple relationship. If the angle of elevation of the sun's rays at a given point on the moon's surface be known at a given time, then a given slope will cast a shadow if its slope angle exceeds the angle of elevation; if its slope angle is less, the slope will be illuminated; if its slope angle is equal to the angle of elevation, the phenomena of grazing incidence will be observed. If a series of photographs taken at frequent intervals during a lunation were available, inspection of these photographs would enable the observer to ascertain the time, for any given slope, at which the incident sun's rays just begin to illuminate the slope.

It is possible with the aid of the Nautical Almanac and Ephemeris to ascertain the phase angle (angle at the moon's center between the lines of sight to the centers of the sun and the earth respectively) for the instant of time at which a given photograph was taken. With aid of an accurate perspective projection chart the angle of incidence of the sun's rays at any point on the moon's surface and for any given phase angle can be read off directly from the chart without computation. From the same chart, printed on celluloid and superimposed on the negative or a print therefrom, the dimensions of any lunar surface feature can also be read off directly in terms of angles and these in turn converted to linear dimensions by use of a small table. By this method the observer is in position with a sufficiently complete set of photographs to reconstruct the shapes, both in plan and section, of lunar surface features not too far (less than 45°) from the center of the moon's disk and to draw therefrom a rough topographic map.

The Moon Committee is fortunate this year in having assigned to its use the 100-inch telescope for photography of the moon during the July lunation. The first photographs were taken on June 30, 1938, and are to continue throughout the lunation until July 24. During this period it is planned

to take photographs on different types of plates at intervals of 5 or 10 minutes during periods of good seeing. It is expected that the series of photographs taken at the Newtonian focus with the aid of the zero corrector lens will form the basis for detailed studies of the topography of many surface elements of the moon. The zero corrector lens may be successfully used between wave lengths 5000 to 6000 Ångström units; beyond these limits chromatic aberration becomes serious. A yellow filter of glass of characteristics approximating Wratten K₂ is used and sensitometer spots through the filter are imprinted on each plate. To reduce halation each plate is backed. The following plates are to be used: Eastman Spectroscopic C₃, D₃, F₃, Solar Green A, and Wratten and Wainwright panchromatic; they are to be developed in the soft Ross elon developer.

On February 1938, the Committee suffered severe loss through the unexpected death of one of its members, Dr. F. G. Pease, who took great interest in the surface features of the moon and in 1919 with the 100-inch telescope procured at its Cassegrain focus the best photographs of the moon that have thus far been obtained. It was in part his enthusiasm for the subject that led to the appointment of our Committee. Dr. Pease gave freely of his time and thought to our work and we shall greatly miss his genial personality and helpful support.

W. S. ADAMS

J. P. BUWALDA

A. L. DAY

P. S. EPSTEIN

E. PETTIT

H. N. RUSSELL

F. E. WRIGHT, *Chairman*

PHYSIOLOGY

Russell, G. Oscar, Ohio State University Speech, Voice Science, and Hearing Research Laboratories, Columbus, Ohio. *Physiological cause of voice quality differences*. (For previous reports see Year Books Nos. 28-33, 35.)

Studies have continued with aid of funds provided by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Some of the more basic facts uncovered in this study are beginning to have their effect on the scientific literature pertaining to the mechanism of the larynx and sound-producing organs in the human being. The last edition of Cunningham's *Anatomy*, for example, points out for the first time that the ventricular bands are capable of constriction independently of any movement in the glottal lips proper. It will be remembered that this was one of the facts which grew out of our vocal cord motion pictures. Since the demonstration was so new and had not been made before, and the observation was so diametrically opposed to previous concepts, it aroused considerable skepticism, at first, except among those who actually saw the film. However, Dr. Leon Strong of the Department of Anatomy at the University of Michigan was induced thereby to undertake a careful histological reworking of the area, which has thrown considerable additional light on the subject.

As has been indicated in our previous reports, these activities in the superior larynx, including those of the ventricular bands, seem to be primarily responsible for a major part of voice quality distinctions. Yet most of these functions which can now be observed and studied directly, by means of the techniques devised in this investigation, not only have heretofore not been noted even in books on anatomy and physiology, but in many cases have been indicated as impossible. The function just referred to was one of these. Since the ventricular bands have their attachments on the same cartilages as the glottal lips, it could not be seen how one set could function independently of the other.

The pulvinar, cartilages of Wrisberg, and other parts of the superior larynx are also just as radically involved, as we have previously stated. As yet, however, others have given practically no attention to these functions.

That the pulvinar can function quite independently of movements in the superior epiglottis seems to be definitely established by the experiments we have thus far performed. We have just initiated a study this year of the physiological action which appears to be there involved. It is not yet in a state where it can be released in article form. Suffice it to say that the muscular contraction which brings about this posterior movement seems to be from above, down as well as back. And the visible posterior termination of the contraction appears to fall just above the ventricular bands forward of the arytenoid cartilage. However, this contraction takes place without involving the upper edges of the epiglottis proper, which in this study have been shown to contract very violently at times, but may in this case remain quite relaxed. That would seem to indicate a function of the arymembraneous muscle.

Certain very low pitch changes are apparently in part likewise accomplished by means of this posterior movement of the pulvinar. It often seems also to be involved in the creation of some guttural qualities. And to a certain extent the opposite type of loud strident and nasal twang qualities seem to be abetted through its partial involvement. The same may be said of those asthenic qualities in the voices of certain individuals, giving what in the past has been classified as "lack of resonance." For if pulled lightly over the voicing glottal wedges the pulvinar appears to serve much as would a soft sponge clamped over the mouth: the voice escapes, but it lacks that "vibrant ringing" quality so often erroneously called "resonance"; and if the sponge occludes the opening too completely, the voice is muffled.

From the beginning it appeared, however, that the major part of voice quality differences was created by the glottal lips themselves. About all we could see was what appeared to be a variation in the thinness or blunt roundness of the interior glottal margin of the lip itself. And that was hardly enough to establish the observation. Actual proof of quality differentiation in the glottal tone was needed.

For some time we have been seeking unsuccessfully to obtain such facts. We sought to contact, through laryngologists, a case or two in which open unhealed wounds immediately superior to the glottis would make possible a direct study of the tone as it emits from the vocal source before it passes through the pharyngeal, buccal, and nasal cavities above. For some proof would thereby be made possible. If the sound could be conducted out directly and the pharynx, mouth, and vocal cavities above be cut off entirely, it would be possible to make oscillographic photographs of the isolated glottal tones which would demonstrate whether any part of the vowel or voice quality was produced in the larynx rather than by intervention of the resonating cavities above. The latter is of course the assumption all but universally made.

In 1872 Dr. E. M. Moore of Rochester, New York, reported such a case in one Edward Matthews.¹ The patient had attempted to commit suicide by slashing his throat immediately above the thyroid cartilage, and at the base of the epiglottis. The edges of the wound cicatrized so that it failed to close, leaving an oval opening two inches long by three-quarters of an inch wide. Dr. Moore reports that when he threw the patient's head back and inserted a sheet of buckskin so as to prevent any possibility of sound passing into the mouth and head cavities above, most of the vowel qualities could be easily created. Only the consonants were badly impaired. This would indicate that certain qualities are created right in the larynx proper.

Furthermore, we were successful in contacting an individual from whom had been removed all those cavities which have in the past been given the credit for creating this so-called "resonance." He was a patient of Dr. George M. Dorrance in Philadelphia. All the sinus and other open cavities above the velum and palate had been completely removed. There remained nothing but one wide megaphone-like opening in the head where they and the nose should have been. We took over a number of voice teachers and acoustic scientists from the convention of the Acoustical Society to observe

¹ E. M. Moore, *Trans. New York State Med. Soc.*, 1872, pp. 276-282.

the case. All were agreed that the carrying power of this individual's voice was certainly not impaired. On the contrary, the loudness of the voice, when the velar sphincter was left open, was, if anything, greater than in the normal individual. That indicated that this phase of so-called "resonance in the voice" is certainly not traceable to any sinus functioning as a resonator to add carrying power to the vocal tone. For every paranasal sinus in this man's head was gone.

Mr. Warren, working with us in the summer session at the University of Wisconsin, is approaching this problem in a different way. He is using an artificial larynx sealed into a cadaver head and making an oscillographic photograph of the resulting tone as he fills up each sinus and varies the size of the ostium and enlarges accessory openings into these nasal so-called resonators. The curve will show whether any change in loudness or quality is created when a sinus is first left normally open, and then filled up with a solid substance. Our first tentative results in three experiments showed no change whatever in the curve. In other words, neither loudness nor quality was changed when the sinus was filled up.

But all this still leaves unsolved any confirmation of Dr. Moore's observation that vowel, much less voice, qualities might be created right in the larynx.

Our major experiments this year have revolved around this question. We devised experiments, making use of our resonometer contact transmitter described in one of our previous reports, to show whether any quality distinctions could be detected right at the vocal cords as the subject produced different vowels. When coupled with a high-powered amplifier feeding into a cathode ray oscillograph, the resonometer transmitter will show the slightest variation of quality traceable to either harmonic or inharmonic tonal partials present in any vibrating surface it touches. But it will not respond to any vibration in the air.

Since the contact button is only about half the size of a dime, if it is placed in contact with the throat on the exterior, right at the point under which lies the glottal lip (or vocal cord), it follows that if any variations in the sound patterns occur as one passes from one vowel or one voice quality to another, absolute evidence is produced showing that the quality vibrations within the glottal lip itself are changing. In other words, the harmonic components in the tone resulting from glottal lip vibration are different, and may be modified at will within certain limits.

It was quite necessary that we be able to make a sound movie record of the subject's face simultaneously with this resultant of the point of contact. Then any variations in the exterior buccal aperture, as well as of the sound track produced by the vocal cavity air-bone vibrations, could be studied as they correlated with the glottal tone shown in the curve on the oscillograph photograph on the same frame with the subject. A large number of such records have been made for us in sound pictures of the subject which we were successful in finally getting completely synchronized with the oscillographic track appearing right on the same frame. This gives us, therefore, the sound emanating from the mouth with its harmonic components accurately enough recorded to make clear distinction as to exactly

what vowel was being produced. This track may thereupon be compared with the contact resonometer oscillograph curve appearing alongside, which of course shows the tone produced in the larynx right at the vocal cord itself.

While the experiments are not yet complete and will necessitate careful study over several years to come, they seem to produce definite evidence that the glottis (rather than the so-called "resonating head cavities") is primarily responsible, first, for the loudness or carrying power of the voice; second, for a substantial part of the vowel quality distinctions; and, third, for much of the voice quality differences we hear.

We are well aware of the fact that these observations are in sharp conflict with the viewpoints generally held to date, and that careful study of the experimental evidence is required before one becomes too positive. So, for example, it is very obvious that both the vibrating source and the natural frequency characteristics of the cavities being stimulated thereby will be respectively modified when the two are coupled. Hence, if one records the curve produced by the vibrator, they may well show changing characteristics due to coupling with cavities above which alone are being modified. But this fact is quite as important to know; and it is one which has been entirely overlooked in all previous considerations of the physiological cause of voice quality differences. Furthermore, it would still be a glottal tone change. Besides, it can even now be tentatively said that the curve characteristics in the glottal tone as picked up by the resonometer are so radically different from voice quality to voice quality, and from vowel to vowel, as to make it very doubtful whether the coupling effect can be assumed to be by any means entirely responsible.

The major part of our activities has been devoted to life-size reconstruction in hard plaster and resilient cast of the exact vocal organ position used by Lawrence Tibbett in the production of different vowels, pitches, and voice qualities. By this means one begins to get a better understanding of relationships, and their effects in the actual human being. This reconstruction can be made accurate to within the width of a pinhead by reason of our X-ray and laryngoperiskopik photographs controlled to within a 0.1 mm. possible deviation. Through the N. Y. A. Board we have been provided with three to six helpers who were untrained in the beginning, it is true, but have gradually become of considerable assistance. This help has of course been without cost to the project. Our major expense this year has been for the sound pictures, but that has been relatively nominal. So that again it has been possible for us to conserve the major part of our funds. Since our two principal projects represent entirely new experimental techniques which had to be perfected, no articles have been published thereon except two of Dr. Robert O. L. Curry.¹

¹Robert O. L. Curry. The cathode-ray oscillograph in speech recording and analysis. *Jour. Scientific Inst.*, vol. 11, no. 5, pp. 162-164 (1934). Printed in Great Britain.

Idem, The mechanism of pitch change in the voice. *Jour. Physiol.*, vol. 91, no. 3, pp. 254-258 (1937). Printed in Great Britain.

PSYCHOLOGY

Ruger, Henry A., Teachers College, Columbia University, New York, New York. *Studies of correlational surfaces*. (For previous reports see Year Books Nos. 27-36.)

These studies have been continued with funds made available by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The work of the past year was concerned mainly with the transfer of higher moments and higher product moments from arbitrary origins to true means. This was completed for four pairs of traits. These were weight and span, stature and span, pull and stronger grip, and sitting height and stronger grip. Forty-one moments and product moments were computed for each age group for each pair of traits. Fifteen consecutive age groups, those from 16 to 30, were employed. In addition, the forty-one moments and product moments about arbitrary origins and for each of the age groups were computed for five more pairs of traits. These moments have been referred to true means in about one-fourth of the total of such operations. A study of the fluctuation and trends of these moments with age and of their relation to corresponding values in the population of 7000 males is to follow. Despite the fact that all scores are residuals from regressions, nonlinear, on age, such trends appeared in the case of correlation coefficients, correlation ratios, regression coefficients, and simple product moments as shown in the earlier studies of this series, *Annals of Eugenics*, vol. 5, pts. 3 and 4. This was true of certain pairs of traits and not of others. The present study is concerned with the behavior of higher product moments under like conditions.

An average force of ten statistical workers under the supervision of, at first, Antonia von Brand and now of E. K. von Brand has been furnished by the Works Progress Administration.

ST. AUGUSTINE HISTORICAL PROGRAM

Chatelain, Verne E., St. Augustine, Florida. *The St. Augustine Historical Program.* (For previous report see Year Book No. 36.)

Financial aid for support of these studies has been supplied in part from funds made available by the Carnegie Corporation of New York for study of problems relating to factors involved in the history of the United States.

The St. Augustine Historical Program completes the second year of its investigations and research with the preparation for publication of the first of a series of studies on the First Spanish and British periods, bearing on the problem of military fortifications and defense strategy in relationship to other elements of growth and development in the region controlled by the Presidio de San Agustin. This study appears in two parts, the first a section of text treating of the defenses chronologically stage by stage as related to the general processes of Spanish and British colonization; the second part is a map atlas which will include, with an introduction and editorial comment, a considerable number of hitherto unpublished manuscript maps principally drawn from Spanish and British archives. In addition, there is already in the course of preparation another general study, analyzing and contrasting the agrarian and colonial policies of the Spanish and British in Florida.

Since the completion of the preliminary survey in March 1937, the staff of the St. Augustine Program has worked steadily at the task of discovering, collecting, and studying the great mass of written source materials existing in this field of American history. Many of these materials are parts of foreign archives, and to date the work has been centered largely upon surveying and dealing with special collections of photostats and transcripts to be found in public and private libraries in America, such as the Lowery, Connor, Brooks, Stetson, and Buckingham Smith materials; and the special series in the Library of Congress and the Clements Library involving the East Florida Papers, the Papeles Procedentes de Cuba, the papers of the Audiencia de Santo Domingo, the British Public Record Office, the British Museum, and the Gage, Haldimand, Clinton, and Shelburne documents, some of them originals, and some transcripts or photostats. Mention should be made also of very considerable map collections with which the staff has concerned itself, located primarily in the Library of Congress and the Clements Library.

Along with this program of research, substantial progress has been made in the field investigations at St. Augustine bearing upon the location, present condition, classification, and history of numerous sites associated with the various events and stages of growth in that area. Since the beginning of the St. Augustine Program, combined historical and archæological techniques have been used in this phase of the work, and these methods have been gradually perfected in meeting the actual conditions of the Program. Mr. Albert Manucy, assistant historian, and Mr. W. J. Winter, archæologist, have had this activity in charge.

A system of "case histories" has now been developed to a point where, with regard to many sites, it is possible to say with some degree of certainty just what has happened through successive stages of history. These case

studies are made for house sites, fortification elements, and other sites where important events have taken place, but where perhaps there are no remains of human structures. Thus the historical and descriptive data include detailed information about the succession of ownership of property, legal descriptions of sites, related environments, and in many cases now fairly complete archæological studies, with field notes, maps, photographs, sketches, and engineering data. A recent study of Fort Picalata, one of the outlying defenses of St. Augustine, is a case in point.

Inasmuch as the St. Augustine Program involves not only historical research, but also the development and use, under the best possible conditions, of existing physical remains of history, these local studies and resulting data on individual sites and structures are especially important in establishing the standards and basis for future civic activity. In this connection, a notable achievement of the past year has been the adoption by the City of St. Augustine, under the authority of an act of the Florida Legislature, of a zoning ordinance, which has as its principal objective the perpetual preservation and control of the physical elements of history within a suitable environmental condition. This zoning measure is a distinctive civic achievement and goes so far beyond the standards generally prevailing today in American communities that it stands without precedent in the field of activity for the preservation of historic sites, and points the way to many possibilities in dealing with such situations.

Commendable progress is now being made upon the preparation of detailed plans or projects for the physical treatment of many of the individual historic sites in St. Augustine. These include architectural, landscape, and general environmental considerations, all seeking to emphasize the preservation and wise use of the historical elements. Among other things accomplished, a complete system of historical markers has been prepared, and is soon to be installed; the local staff has been in charge of the preparation of these markers, as well as of their proper location.

Intensive study has been given during the past year to the entire system of inner defenses, including the three northern lines or parallels. This work has involved an adaptation of the method of case study, suggested above, to more general areas, rather than particular sites. Since St. Augustine during all the Spanish and British periods was primarily a military *presidio*, this element in the study deserves special emphasis, and must always be taken into consideration in dealing with other problems of community growth.

In so far as its scope and methods are concerned, the St. Augustine Program has been closely connected from the beginning with other activities now being carried on by the Institution. The approach at St. Augustine continues to be on the basis of cooperation in use of information from all branches of science and history that can contribute. Illustrative of this point is the fact that special studies in medical history are now under way under the auspices of the St. John's County Medical Society; also certain linguistic and group culture studies, bearing on the Minorcan element, have been undertaken under the sponsorship of the Spanish Institute of Florida and the St. Augustine Historical Society.

Finally, it may be noted that many of the earlier objectives of the historical program of Carnegie Institution of Washington, having to do with the use of new materials and with the study of the beginnings of American colonization, are being furthered by the studies now going forward in the St. Augustine Program. The work, now ready for publication, dealing with the military frontier and its defenses, and that in the process of preparation, bearing upon the analysis and comparison of the early Spanish and British colonization systems, may contribute to other studies of early American history.

SEISMOLOGY

California Institute of Technology. *Report on cooperative researches at the Seismological Laboratory, Pasadena, California.*

Although the active direction of the Seismological Laboratory at Pasadena passed on January 1, 1937 to the California Institute of Technology, operating through a committee consisting of Dr. John A. Anderson, Mr. Harry O. Wood, Dr. Beno Gutenberg, and Dr. John P. Buwalda, Chairman, no extensive change has occurred in the program of research of the Laboratory and in the personnel conducting it from that date to the end of the year under review, June 30, 1938. The recording and the study of the records of local earthquakes, a program undertaken when the Laboratory was founded, continues to absorb the larger part of the effort of most of the members of the staff and of the funds available. This research program is unique in that in most seismological laboratories of the world major attention is given to teleseisms or distant earthquakes. The attention of the Pasadena Laboratory, with its six outlying stations scattered through southern California, has been concentrated during the past decade not merely on the more important earthquakes occurring in this region but on shocks of all magnitudes, the barely registerable disturbances commonly contributing data of value comparable to those derived from more important ones. This very intensive study has yielded an enormous amount of data bearing on such questions as the distribution of seismic activity of the different parts of southern California, the relation of earthquake origin to the active faults of the region, the depths of the foci of shocks, the waxing and waning of the activity in particular localities, the relation of epidemics of minor shocks to stronger earthquakes, the energy dissipated in large and small shocks, the differences in velocity of earthquake waves in different types of rock and in different directions along and across the major structures of the country, the amplitude and period of oscillation in different parts of an earthquake, and the nature of the complex motion. These and related data are of very great value to structural engineers in designing earthquake-resistant buildings and other structures. While much of the effort is of course directed toward the solving of various scientific questions relating to the nature and causes of earthquakes, another major purpose in the accumulation of this vast amount of information about local shocks and its interpretation has been the contribution it makes to the only feasible solution of the problem of safety in earthquake countries: the building of office, manufacturing, residential, and other structures of such resistance that neither the shock nor the conflagration which customarily follows it can destroy them. Safety of buildings virtually means safety of life in earthquakes.

In addition to the local earthquake study much attention has also been given to certain types of distant earthquakes, especially those with unusually deep origins; to the structure of the deep interior of the earth; to the velocities of different types of waves through the interior and the reflections of wave trains from the inner and outer surfaces of the shells of which the earth is constituted; to the design and construction of a new type of seis-

mograph, and of a motion picture film recorder for seismographs, as well as a considerable number of other new types of equipment.

Some of the activities of members of the staff of the Laboratory are summarized in the following paragraphs.

Dr. Gutenberg and Dr. Richter completed an investigation, and published the results, on the depth and geographical distribution of deep focus earthquakes.

The field operations involved in a determination of the depth of the fill in Yosemite Valley and therefrom the form of the bedrock glacial trough constituting the valley were completed by Dr. Gutenberg and Dr. Buwalda and the results are being prepared for publication.

Dr. Gutenberg wrote several chapters for the bulletin "Physics of the earth" being published by the National Research Council, and summarized work completed with the California Institute seismic reflection equipment in an article in "Ergebnisse der kosmischen Physik."

Much attention was given by Dr. Gutenberg during the year to further investigation of the travel time and velocities of earthquake waves and to the question whether travel times differ in different regions. With Dr. Richter the so-called diffracted waves through the core were also studied, and a new explanation for these waves was proposed, based on the assumption that these waves are direct waves through the core. Besides studies of records of earthquakes a theoretical study of this type of wave was also made. In connection with this research the travel times of various types of waves were revised by using data from deep focus earthquakes, and the velocities of the waves in the interior of the earth were recalculated. They seem to indicate that no discontinuity exists between a depth of 60 km. below the surface of the earth and the surface of the core. Dr. Gutenberg and Dr. Richter also investigated the effect of surface layers on the velocities between the origin and points within 30° of the origin, in an attempt to explain the observations that in the Montana earthquakes of 1935 the longitudinal waves arrived several seconds too early at stations east of the Rocky Mountains.

Dr. Gutenberg and Dr. Benioff undertook a research on pressure waves in the atmosphere to determine whether they bear any relation to microseisms. It was found that sometimes air waves with a period of a few seconds occur, but the relation of these to microseism is not convincing. An incidental result of this study was that it was found that the equipment registered accurately the air waves produced by the target practice of the Navy off the California coast, and using the data furnished by the Navy it was found on calculating the velocities that the waves arrived late at the Seismological Laboratory. It was concluded that the waves traveled in a layer some 25 miles above the surface having a temperature above that of the air at the surface.

Dr. Richter continued the study and the supervision of the measuring of the local earthquake records during the year. Local seismic activity continued at about normal level, except that a gradual recrudescence of activity in the Mojave Desert occurred, after a pause since about 1932. An increase of small shocks was also noted in the Boulder Dam region, which may be

related to the weighting of the crust as a result of the filling of Lake Mead, the reservoir behind the dam. The strongest shock in the southern California region was one on May 31, 1938, originating in the Santa Ana Mountains region, probably on the Elsinore fault. This disturbance was felt over a large part of the southern part of the state but it did no damage. Distant earthquakes are now being recorded and catalogued more completely than before, owing partly to the courtesy of the U. S. Coast and Geodetic Survey in permitting study of seismograms being written at Tucson.

Owing partly to the development of a fully equipped instrument shop in the Laboratory, rapid progress was made during the year by Dr. Benioff and his assistants in the design and construction of several new and important types of instruments, as indicated below.

New electromagnetic seismograph. A new electromagnetic seismograph employing a moving conductor type transducer was developed. The inertia reactor has a mass of approximately 100 pounds. The period is adjustable from approximately 0.8 second to 4 seconds. Damping is electromagnetic and is obtained from the reaction of the output currents. The spring is of new type and is made up of a group of 12 flat steel strips acting in the form of bent columns. The new seismograph uses either a $\frac{1}{4}$ -second or a 120-second galvanometer for recording. The response is very nearly the same as that of the Benioff variable reluctance seismograph, except at high seismic frequencies, where the lower transducer impedance of the new form results in a relatively greater response. The new instrument can be built for approximately half the price of the older form.

Motion picture film recorder for seismographs. The relatively high cost of photographic paper used in the local network of stations (approximately 20 cents per instrument per day) stimulated an investigation into the possibilities of motion picture film as a recording medium for seismographs. Accordingly a film recorder was designed and built in the laboratory shop. For the 30×90 cm. bromide paper the new recorder substitutes a strip of standard 35-mm. motion picture positive film 90 cm. long. The recording speed is reduced to $\frac{1}{4}$ mm. per second and the line spacing to 1 mm. It was necessary to substitute metal belts and pulleys for the final two sets of gears in the drum rotation mechanism in order to eliminate variations in drum speed caused by gear teeth. The cost per day per instrument with safety film is approximately 4 cents as compared with 20 cents with paper. Measurements on the film records disclose the unexpected finding that the accuracy is ten times as great as that of paper records.

Electromagnetic microbarograph. An electromagnetic microbarograph was developed for the purpose of recording atmospheric waves in the frequency range $1/20$ to 10 cycles per second. The responding element consists of a moving conductor, permanent magnet, cone type, loudspeaker unit. This is mounted over a circular hole in a sealed cubical container of about $\frac{1}{4}$ cu. m. capacity. Changes in atmospheric pressure thus produce movements of the speaker cone with the result that electromotive forces are induced in the speaker voice coil. The coil is connected to a standard seismograph short-period galvanometer ($\frac{1}{4}$ -second period) recorder, which re-

cords the currents. Although the instrument uses no amplifier its sensitivity is sufficient to reach the level of general atmospheric unrest. Battleship gunfire 160 km. distant has been recorded.

New recorders. A new type of recorder was developed and installed in all the seismographs of the local network. In the new recorders the light beam falls vertically from above on the top surface of the recording drum with the result that the spot can be easily observed and adjusted in position, focus, or intensity. The new recorders have been equipped with ballast lamps for maintaining constant lamp current regardless of battery voltage fluctuations.

Replacement and repair. New automatic radio recorders and new automatic radio receivers for network synchronization were developed and installed in all stations. New automatic radio receivers for primary time signals from Mare Island were developed in collaboration with Mr. F. E. Lehner and have been installed in all stations. All stations were completely rewired and overhauled. The Haiwee vertical seismometer was moved some 1700 feet to avoid vibrations due to a large pump in the vicinity of the station. The recorder operates in the station and is connected to the seismometer by a lead-sheathed cable. The portable seismograph assembly was overhauled and a new radio installed. A N-S component strong motion seismograph was installed. A spare 10-cycle drive for recording drums was built. The construction of a measuring engine for film records is about two-thirds completed.

OFFICE OF PUBLICATIONS ¹

FRANK F. BUNKER, EDITOR

In the report of the Office of Publications for last year (Year Book No. 36) description and characterization of the publishing practice and program of the principal administrative units of the Institution's organization was undertaken.

The space limitations of the report were such that the organization and work of but three of the major divisions could be sketched. These were: the Division of Animal Biology with its lesser units of the Department of Embryology, the Department of Genetics, the Nutrition Laboratory, and the Tortugas Laboratory; the Division of Historical Research with its Section of Aboriginal American History, Section of Post-Columbian American History, and Section of the History of Science; and the Division of Plant Biology with its many small groups of investigators studying various problems which work in the plant sciences has developed.

It should be repeated that the regular staff of investigators of the Institution is organized in Departments and Divisions, each major unit being engaged in coordinated study of related problems. In addition, a number of investigators (Research Associates), affiliated with other agencies, are pursuing specific investigations under short-term grants conferred by the Institution. Some of the investigations made by the Research Associates are conducted in close cooperation with the work of Institution departments. Indeed, in some instances, the department head invites specialists in various subjects to join his group for a time in order that some item of his departmental program may be covered for which he is not suitably staffed. On the other hand, in instances, the studies upon which the Research Associates are engaged are independent of departmental programs and of departmental supervision.

Reports on the progress of the investigations thus conducted are constantly being published, some in monographic form for permanent record, some in scientific journals and in the proceedings of scientific societies for the current use of specialists, some in form suited to the audiences served by the newspapers and the popular magazines, but all finding place, in summary or bibliography, in the Year Books of the Institution.

In the present report the sketch of the Institution's publishing practice and program will be extended to embrace the remaining units of the staff organization.

THE GEOPHYSICAL LABORATORY

Investigations to determine the modes of formation and the physical properties of the rocks of the earth's crust were begun under the auspices of the Institution in 1904, when grants were made for special researches to be carried on in Washington at the office of the United States Geological Survey.

In December 1905, plans for the erection and equipment of a laboratory for the experimental work previously conducted by Dr. Arthur L. Day

¹ Address: The Carnegie Institution of Washington, Washington, District of Columbia.

were approved. A site of five acres on Upton Street in Washington was purchased and a building suitable for the purpose was erected. In July 1907 Dr. Day, who had been appointed Director, and his staff took possession of the building and began organizing the work which has been conducted continuously ever since.

The investigations undertaken by the Laboratory staff have included a number of silicate solutions, corresponding to particular groups of rock-forming minerals, and recently some in which water and carbon dioxide have been associated.

Investigations have also been made of the quantity of heat involved in mineral reactions and in the change of state from liquid to solid; also in the study of solutions it has proved possible to show the manner of separation in magmas through differences in density between the minerals first to crystallize and the remaining magma. It has even proved practicable to approach certain active volcanoes and to make collections of the gases for laboratory study.

So, also, the Laboratory has undertaken studies of atomic structure in crystals; of the radium content of rocks from widely separated regions in continental areas and also from samples taken from the ocean bottom; and of the compressibilities of rocks and minerals and the effect of pressure upon all the problems of mineral and rock formation.

Work in seismology was inaugurated by the Institution in 1921 with appointment of an Advisory Committee, of which Dr. Arthur L. Day was Chairman. Studies of earth movement in California have been undertaken with effective cooperation of many agencies, and a new but extremely simple type of seismograph has been developed. For the period from July 1, 1926 to January 1, 1937 the Institution, upon agreement, utilized the Seismological Laboratory of the California Institute of Technology for the initiation and conduct of the seismological program in California. Since the latter date, California Institute has been operating this Laboratory, the Institution agreeing to continue financial support for a limited period.

The results obtained in the course of the investigations at the Laboratory are in most instances published in the technical journals devoted to physics, chemistry, ceramics, mineralogy, and geology. Although the researches bear either directly or indirectly on geophysical problems, the individual research is usually merely a phase of one of the more specific sciences.

Papers, when ready for publication, are sent in each instance to what is believed to be the most appropriate journal, due regard being had for the audience reached by the journal and the likelihood of publication. An imposing number of technical journals are utilized in this manner. Indeed, during the past three years papers from the Geophysical Laboratory have appeared in no less than twenty-one regularly published journals and three other publication mediums. Formerly, much use was likewise made of foreign journals, especially the *Zeitschrift für unorganische und allgemeine Chemie* in Germany, and the *Philosophical Magazine* in England.

Copies of the journals containing Laboratory papers are readily available in the libraries of the principal countries of the world and are received by many scientific men as well. The distribution of papers prepared by

the staff of investigators is considerably increased through invitation sent to a selected list of 1400 names, representing all parts of the world, to indicate desire for reprints of the published papers. Abstracts of all the published papers, now numbering 990, are also published in the Year Books of the Institution.

When a series of researches is sufficiently advanced to form a reasonably complete group they are issued by the Institution in monographic form. Also, in several instances commercial publishing concerns have brought out books dealing with subjects under investigation at the Laboratory which were written by members of the staff.

THE MOUNT WILSON OBSERVATORY

The Mount Wilson Observatory was established in 1904, after a careful test of atmospheric conditions at various promising points in California, Arizona, and Australia had been made. The site selected is on the summit of Mount Wilson, in Southern California, 5714 feet above sea level. The laboratories, instrument and optical shops, and the offices for the measurement and reduction of astronomical and physical photographs and for other activities not requiring the favorable atmospheric conditions of the mountain station are situated in Pasadena. From this point the summit of Mount Wilson, twenty-eight miles distant by mountain road, may be reached in one hour by automobile.

The Observatory was established for the purpose of studying the structure of the universe and the evolution of celestial bodies. The observational program comprises series of closely related investigations, so chosen as to aid in interpreting one another, and all directed toward a common objective. The underlying scheme is based upon an intensive study of the sun, the only star near enough to the earth to be examined in detail.

The constitution of matter is also being studied in cooperation with the Norman Bridge Physical Laboratory and the Gates Chemical Laboratory of the California Institute of Technology.

Three telescopes are provided on Mount Wilson for solar observations: the Snow horizontal telescope, the 60-foot vertical tower telescope, and the 150-foot tower telescope. These instruments were designed and constructed by the Observatory staff to permit sunspots, prominences, and other phenomena of the solar surface and atmosphere to be investigated under conditions as favorable as those attainable in the study of artificial light sources in the best of physical laboratories.

These three telescopes are used regularly for photographing the sun's surface and its atmosphere; and for investigations of the solar vortices and magnetic fields connected with sunspots, the general magnetic field of the sun, the law of the sun's rotation, and the displacements of solar lines and their bearing on the Einstein theory of relativity. The results thus obtained have been of great service in the initiation and interpretation of researches on stars and nebulae.

Four other telescopes, each equatorially mounted and provided with special accessories, are employed for night observations. One of these is

a 10-inch Cooke photographic refractor of 45 inches focal length, permitting large areas of the heavens to be photographed on a single plate. The other three are reflectors having apertures of 20 inches, of 60 inches, and of 100 inches, respectively.

The upper section of the tube of the 100-inch telescope is removable, permitting several different optical combinations to be made by attaching plane or convex mirrors, giving equivalent focal lengths ranging from 42 to 250 feet. Observations, almost exclusively photographic, are made from observing platforms attached to the dome or to the telescope mounting, or from within a constant-temperature laboratory, where a star image can be formed by one of the combinations of mirrors. The great light-collecting power of this telescope permits the faintest known stars to be photographed directly on the sensitive plate and makes it possible to study a great number of objects with aid of spectrographs of high and low dispersion. The 100-inch telescope is also especially adapted to the photographic and spectroscopic examination of nebulae, where minute details of structure are beautifully revealed by its large-scale images.

These telescopes, in use throughout every clear night, are also employed for the photographic measurement of the trigonometric parallaxes of stars and nebulae, the determination of stellar motions in the line of sight, the measurement of the distances and intrinsic brightness of stars by means of the spectroscope, the determination of stellar magnitudes, the investigation of star clusters and the scale of the stellar universe, the detection of changes in nebulae and the measurement of their distance, and a great variety of other studies.

Special attention is given by the Observatory to the invention and use of new instruments and methods and the application in astronomy of devices previously employed only in other branches of science. A notable illustration is the successful application of Michelson's interferometer to the measurement of the diameters of several stars, some of which have been found to exceed 300,000,000 miles. A 20-foot interferometer attached to the 100-inch reflecting telescope was built for this purpose in the Observatory shops, which are completely equipped for all classes of machine and optical work. In order to extend the observations to smaller and somewhat fainter stars an interferometer of 50 feet maximum aperture, mounted equatorially, has been completed and is now in operation.

Another cardinal principle in the policy of the Observatory is the imitation and interpretation of celestial phenomena by means of laboratory experiments. The physical laboratory in Pasadena is provided with special electric furnaces, flames, arcs, sparks, and vacuum tubes; apparatus for producing intense magnetic and electric fields, high and low pressures, and other devices for imitating the conditions existing in the sun, stars, and nebulae; together with spectroscopes of various types, echelons, Fabry-Perot and Michelson interferometers, and auxiliary apparatus for analyzing the light emitted under any desired conditions from controlled sources. The laboratory equipment also includes a 500-kilowatt generator for experiments requiring powerful direct currents.

The publications of the Observatory for the most part appear as papers

in the *Astrophysical Journal*. Reprints of these papers comprise a series entitled "Contributions from the Mount Wilson Observatory," and as such are distributed, as issued, to a list of about 450 corresponding institutions and individuals.

The "Contributions" include full discussion of individual problems, or of definite phases of some larger problem, and detailed statements of the evidence on which the conclusions are based. They consist of articles and short monographs which first appear at irregular intervals in the *Astrophysical Journal* and then are reprinted with continuous paging to provide for subsequent binding in volumes of about 500 pages.

The arrangement with the *Astrophysical Journal* is such that the results of investigations receive prompt publication and wide circulation, including the regular subscription list of the *Journal* in addition to the list of correspondents of the Observatory, at a cost considerably less than that which independent publication would entail.

In addition to the "Contributions," brief preliminary statements, including an outline of the evidence, covering the results of important investigations are published in the *Proceedings of the National Academy of Sciences*. These "Communications," as they are called, are reprinted and distributed to correspondents, as with the "Contributions." A "Communication" is usually followed by an amplified treatment of the problem in question and is accorded place in the "Contributions" series.

At infrequent intervals the Office of Publications of the Institution publishes monographs and catalogues which are too long for inclusion in the "Contributions" series. These volumes are sent to the depositories of the Institution and to special lists of correspondents, which vary with the subject material of the volume.

One such publication that is noteworthy has just been brought out in this manner. It is: "Magnetic Observations of Sunspots," by George E. Hale and Seth B. Nicholson. This publication, appearing in two parts, has been in course of preparation for many years. It describes the solar telescopes of the Mount Wilson Observatory and gives the history of their development. In it the observations and theories which led Dr. Hale to discovery of magnetic fields in sunspots are discussed, and the methods and equipment used in measuring their field strengths and polarities are described in detail. A scheme for classifying sunspots magnetically is given and all the spot-groups observed from 1917 to 1924, inclusive, are classified for each day. A law describing the magnetic properties of sunspots is deduced from the observations.

Part II of this work comprises the daily magnetic observations of each sunspot observed over the entire seven-year period. The observations are recorded on drawings of the solar disk reproduced on a scale of seven inches to the sun's diameter.

The publishing program of the Observatory also includes provision for contributing minor articles and miscellaneous notes, too brief for inclusion in the "Contributions" series, to issues of the *Publications of the Astronomical Society of the Pacific*, which appear bi-monthly and which have a

wide professional circulation. These articles, as reprints, are obtained for Observatory use but are not distributed generally.

As with all Department heads, the Director of the Observatory sends an annual report to the President of Carnegie Institution, which is published in the Year Book of the Institution and distributed in reprint form to the regular list of correspondents of the Observatory. The reports summarize the scientific work of the year, including the activities in instrument design and construction, and record the changes in organization and personnel. Taken in their entirety these reports comprise a brief scientific history of the Observatory.

THE DEPARTMENT OF TERRESTRIAL MAGNETISM

The Department of Terrestrial Magnetism was formally established in 1904 by the Institution in general accordance with a plan for an "International Magnetic Bureau," submitted by Dr. Louis A. Bauer in 1902. The purpose of the proposed bureau was "to investigate such problems of world-wide interest as relate to the magnetic and electric conditions of the earth and its atmosphere, not specifically the subject of inquiry of any one country but of international concern and benefit."

Since its founding, the Department has been engaged in investigating the phenomena of terrestrial magnetism and electricity, with the object of better defining the laws which govern their manifestations and learning, if possible, something of their nature and causes.

First, data from all parts of the earth were accumulated in order to obtain a general picture of the magnetic and electric conditions and variations, on the basis of which theoretical considerations could be more firmly built. Accordingly, during the period 1905 to 1937 some 200 magnetic exploratory expeditions were sent to remote and little-explored regions and to countries in which either there were no established organizations for magnetic work or existing agencies could not undertake such work and welcomed the co-operation of the Department.

Magnetic and geographical data have thus been obtained at over 6000 stations. About 700 of these localities have been revisited, some of them repeatedly, to determine the progressive changes in the direction and intensity of the earth's magnetism. The problems presented by these so-called secular variations are important particularly in connection with their possible indication of conditions in the earth's crust and interior.

Concomitantly with the land magnetic work a magnetic survey of the oceans was undertaken, first in the Pacific Ocean, as, for that ocean particularly, magnetic data were urgently needed for the correction of magnetic charts and for the studies of investigators. During August 1905 to May 1908, three cruises were made with the chartered brigantine *Galilee*, aggregating 63,834 nautical miles, or 73,511 statute miles.

The work at sea was done subsequently by a non-magnetic vessel, the *Carnegie*, of special construction, built by the Institution. Launched at Brooklyn, New York, June 12, 1909, she made seven cruises in all the oceans between latitudes 80° north and 61° south. The *Carnegie* was de-

stroyed November 29, 1929, by an explosion while in the harbor of Apia, western Samoa, when about one-half of her Cruise VII had been completed. The magnetic and electric survey of the oceans had then been so far advanced that the Trustees of the Institution decided not to replace her.

The aggregate length of the *Carnegie's* seven cruises, August 1909 to November 1929, was 297,579 nautical miles, or 342,681 statute miles; thus the total combined length of the cruises of the *Galilee* and *Carnegie* was about 16.5 times the earth's circumference.

As the earth's magnetic and electric conditions are subject to continual change, the Department observes and records the changes at two magnetic observatories in the Southern Hemisphere, where few such stations exist; one of these is at Watheroo, Western Australia, the other near Huancayo, Peru, at an elevation of about 11,000 feet above sea level.

At these observatories continuous registrations are obtained of the variations of the magnetic elements, of the potential gradient and electrical conductivity of the atmosphere, of earth currents, of the ionization of the upper atmosphere (the ionosphere), and of meteorological and radio phenomena. Both observatories make special spectrohelioscopic observations daily and at Huancayo seismographs (since 1932) for the three components, as also a cosmic-ray meter (since 1935), are continually recording. The ionospheric records furnish data particularly useful for the study of the ionization of the upper atmosphere and cosmic radiation in relation to correlations of these phenomena with terrestrial magnetism and electricity.

Special investigations and experiments are made at the laboratories in Washington on fundamental problems in the structure of matter, magnetism, and electricity, and on the application of physical methods developed in the laboratory to the investigation of geophysical phenomena concerned with electricity and magnetism.

Among the more important items of this part of the program is the continued improvement of instrumental equipment for more intensive study of the ionosphere by radio methods. Another important feature is the development of laboratory sources of high voltage and high-voltage vacuum tubes of special design for investigations of atomic and nuclear physics. Investigations of this type bearing on the structure and reactions of atomic nuclei are highly important in the problems of modern physics pertaining to the general structure of matter. A knowledge of the atomic nucleus and of the properties of the basic particles of which atoms are built is a necessary step toward the understanding of the nature and laws of magnetism.

The results of these studies are made widely available through various channels.

The Office of Publications of Carnegie Institution has published a series of six quarto volumes entitled "Researches of the Department of Terrestrial Magnetism." These volumes contain the results of all the magnetic observations made on land and sea during the period 1905 to 1926. Volumes VII and VIII of the series, to contain the results obtained at the Huancayo and Watheroo magnetic observatories, are nearing completion and will be published shortly.

In preparation is a series of quarto volumes on the oceanographic and meteorological results obtained on the *Carnegie*, Cruise VII, 1928-1929. The first three volumes will relate to physical and chemical oceanography (two volumes) and to biological results. The fourth and fifth volumes will deal with the biological results (one volume) and the meteorological results of the cruise.

The published papers, of which over 1600 have appeared, bear upon all phases of the varied activities of the Department. Taken together they comprise a representative record of what has been done in terrestrial magnetism and electricity and kindred subjects during the past three decades. Various technical journals afford the means whereby the papers prepared by the Department staff are widely distributed. Among the journals making generous use of this material are the following: *Terrestrial Magnetism and Atmospheric Electricity*, the *Physical Review*, the *Journal of the Institute of Radio Engineers*, *Nature*, *Zeitschrift für Geophysik*, the *Scientific Monthly*, *Science*.

The Statistics of Publications and the Bibliography follow.

STATISTICS OF PUBLICATIONS

The table which follows gives the Institution's yearly production of monographic publications, now totaling 728 volumes, comprising 213,442 pages of printed matter.

Production of monographic publications

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	6,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
1930.....	15	4,096	844	4,940
1931.....	14	4,017	1,343	5,360
1932.....	16	2,155	2,588	4,743
1933.....	22	4,256	1,370	5,626
1934.....	13	3,030	1,206	4,236
1935.....	9	1,742	813	2,555
1936.....	13	3,395	1,745	5,140
1937.....	25	2,795	1,975	4,770
1938.....	16	3,489	1,068	4,557
Total...	728	152,932	60,510	213,442

In addition, during the year, the Institution has issued the following: Thirteen numbers in its Supplementary Publication Series, comprising 13 articles, chiefly Institution lectures, totaling 227 printed pages, illustrated with many cuts; 12 numbers of the News Service Bulletin, totaling 94 printed pages and carrying 72 illustrations; and 5 numbers of the Clip Sheet, con-

taining 21 short articles relating to the work of the Institution, suitable for use of the press.

Receipts from sales of publications

Year	Index Medicus	Year Book	Miscellaneous Books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.09
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
1934.....	81.60	50.31	4,500.60
1935.....	29.60	73.28	4,118.52
1936.....	16.40	71.10	5,639.99
1937.....	47.60	88.10	4,528.49
1938.....	109.50	94.80	4,866.75
Total.....	111,844.20	2,349.53	221,562.30

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THE CURRENT FISCAL YEAR

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- No. 330 HACKETT, C. W. Historical documents relating to New Mexico, Nueva Vizcaya, and approaches thereto, to 1773. Collected by ADOLPH F. A. BANDELIER and FANNY R. BANDELIER. Vol. III. Octavo, xii + 532 pp.
- No. 338 STOCK, LEO F. Proceedings and debates of the British Parliaments respecting North America. Vol. IV, 1728-1739. Octavo, xxvii + 888 pp.
- No. 469 ANTEVS, ERNST. Rainfall and tree growth in the Great Basin. (Edited by J. K. WRIGHT.) Octavo, vii + 97 pages, 2 plates, 7 text-figures.
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- IV. CHANEY, RALPH W. The Deschutes flora of eastern Oregon. Pages 185-216, 7 plates.
- V. CONDIT, CARLTON. The San Pablo flora of west central California. Pages 217-270, 7 plates, 1 text-figure.
- No. 487 Contributions to Palaeontology from Carnegie Institution of Washington. Octavo, (Papers I to III were reported in Year Book No. 36.)
- IV. SCHULTZ, JOHN R. A late Quaternary mammal fauna from the tar seeps of McKittrick, California. Pages 111-215, 17 plates, 12 text-figures.
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